PERFORMANCE PREDICTION OF A FOLDING FIN AIRCRAFT ROCKET USING DATCOM, SENS5D, AND 6DOF GEM

A

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By

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Abstract

An approach for the performance prediction of a Folding Fin Aircraft Rocket (FFAR) is presented. This prediction was compiled by calculating the gravimetrics, aerodynamics, and trajectory for a FFAR. The trajectory analysis utilized four computer codes: Rogers Aeroscience Rocket Performance Software, NASA Wallops Sens5d Trajectory and Wind-Sensitivity Calculations for Unguided Rockets, the United States Air Force (USAF) Stability and Control DATCOM, and the NASA Langley Research Center LRC-MASS program (GEM). Computations were performed for a rigid body configuration. This analysis was compared to radar data collected during the flight of a FFAR launched in February 1997 at the Poker Flat Research Range. The comparison shows good agreement between the flight data and the predicted apogee and impact point of the vehicle. In addition, static and dynamic stability analyses were completed for the FFAR.

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1 Introduction and Literature Review

1.1 Introduction

This Graduate Thesis involved the performance prediction of a Folding Fin Aircraft Rocket (FFAR). In February 1997 a FFAR was launched on a noninterference basis at Poker Flat Research Range. Before the flight a wind weighting team collected wind data and during the flight a NASA radar team tracked the rocket. This radar data was then compared with a predicted trajectory compiled by utilizing four computer codes: Rogers Aeroscience Rocket Performance Software, NASA Wallops Sens5d Trajectory and Wind-Sensitivity Calculations for Unguided Rockets, the United States Air Force (USAF) Stability and Control DATCOM, and the NASA Langley Research Center LRC-MASS program (GEM).

The performance prediction of the FFAR began with a solid rocket propulsion analysis of the FFAR MK40 motor, which included calculating the propellant burn rate, core radius of the propellant grain, motor center of gravity (cg), vehicle cg, and the pitch and radial moments of inertia. Next an input file for a program called Rogers Aeroscience was created. This program provided an estimate of the altitude vs. mach number curve for the FFAR by using the Runge-Kutta method in conjunction with the motor specifications and rocket configuration.

The next program used in the prediction was the USAF Stability and Control DATCOM. This program utilized the altitude and mach numbers generated by the Rogers Aeroscience code, and calculated the aerodynamic coefficients for the vehicle in flight. These coefficients included drag, lift, pitching moment, and resultant normal force. By combining these coefficients with the gravimetrics of the vehicle and the wind data, a 5 degree of freedom wind weighted trajectory was calculated by using a program called Sens5d. The purpose of wind weighting was to produce a trajectory which included wind effects and would have the same impact point as a no wind trajectory. This Sens5d trajectory was used to complete the ground and flight range safety plans.

In the final prediction step, a six degree of freedom code: LRC-MASS (GEM), was utilized. This code, which computed a dynamic trajectory model, incorporated the spin rate of the rocket into the trajectory . At this point the data indicated if pitch roll coupling or other dynamics that degrade the apogee were present.

1.2 Literature Review

Throughout this thesis many texts, journals, and papers were used to more fully understand the stability, trajectory, and propulsion concepts. Initial books used which define the basics of flight, equations of motion, and trajectory equations in reduced form were [3] [4] [11] [19]. Two of the papers which described the different dynamics that were taking place, including pitch roll coupling and coning angles, were [10] [14]. Both a Minimum Stability Analysis (Montag 1973) [14] and Balancing Consideration For Rocket Vehicles and Concepts (Long) [10] were used at length to develop the framework of what coning means and how it develops during the flight. Minimum Stability Analysis describes some of the criteria for coning to be present, including how the roll rate and natural pitching frequency relate to it. Balancing Consideration For Rocket Vehicles and Concepts details how the geometric, principle, and spin axis relate to the vehicle coning and what type of imbalances may introduce coning into the flight. In addition, there were many books which aided in the areas of dynamics, aerodynamics, and fluid flow. These include [1] [2] [6] [9] [15] [16] [18] [25] [26]. One book that stands out among these is Flight Stability and Automatic Control (Nelson 1989) [16]. This book details the stability requirements including the moments and derivatives in both the lateral and longitudinal directions as well as the rolling motion. It described the concepts behind the equations and gives examples of stable and unstable aircraft. This helps to understand what stability means before trying to apply it to a sounding rocket. In conjunction with the above, many texts on propulsion, mass properties, and wind effects were consulted. A few of these texts were [5] [7] [8] [12] [13] [22]. For the details of operation on the computer codes, the corresponding users manual and the supplementary guides were used [17] [20] [21] [23]. In addition, many personal communications were used which included people from Poker Flat Research Range, NASA Wallops, and Navy Ordinance at Indian Head.

2 Folding Fin Aircraft Rocket Description and Launch

2.1 Description

The 2.75-inch Folding Fin Aircraft Rocket (FFAR) was originally developed for use as a weapon in the US rocket arsenal. Together with the M-6 machine gun, the suppression rocket weapon was the primary armament on the army Iroquois helicopters operating in Vietnam. Since then the FFAR has been successfully employed as a ground-launched radar test rocket by NASA. It is also being utilized as the rocket for a payload carrying dart, is used for the testing of aerodynamic models, and is also used to flight test components under large "g"-loading.

The FFAR launched for this research had a total length of 47.4625 inches (fins extended) and an outer diameter of 2.75 inches (Figure 1). The individual section lengths and weights are summarized in Table 1. In addition, the conical steel nosecone had a bluntness radius of .5 inch, and the payload section housed a flare which was used as a tracking aid (Figure 2). The flare has a 12 second minimum burn time and an output of 200,000 - 250,000 candlepower (176,000-221,000 watts). The motor used was a MK40 Mod 0, that had a solid double base propellant, and burns for approximately 1.77 seconds. It is called "double-base" because it has two main or "base" ingredients: nitrocellulose and nitroglycerin. The four aluminum fins (Figure 3) are in a folded back position when placed in the cylindrical tube launcher (Figure 4), then spring into the open position once the rocket leaves the launcher and come to rest in their flight position which is at a 41 degree sweep angle. The last inch of the trailing edge is folded to a 45 degree diagonal to help spin stabilize the rocket. The other contributing factor to the spin rate is the scarfed nozzles. The MK40 motor uses four nozzles which have a 56 degree angle at the exit. This angle allows the exit flow to be turned which induces the additional spin rate.

SECTION	LENGTH (IN)	INNER DIAMETER (IN)	OUTER DIAMETER (IN)	WEIGHT (LB)
NOSECONE	3.6875	solid	--------	2.003
PAYLOAD	6.375	1.75	2.75	6.649
FLARE	6	-------	.75	.5
MOTOR	33.8	varies w/ time (.559-1.21)	2.75	varies w/ time (10.71-4.15)
FINS	5.5	width=1.25	thickness=.125	1.046

Table 1. FFAR Dimension and Weight Summary

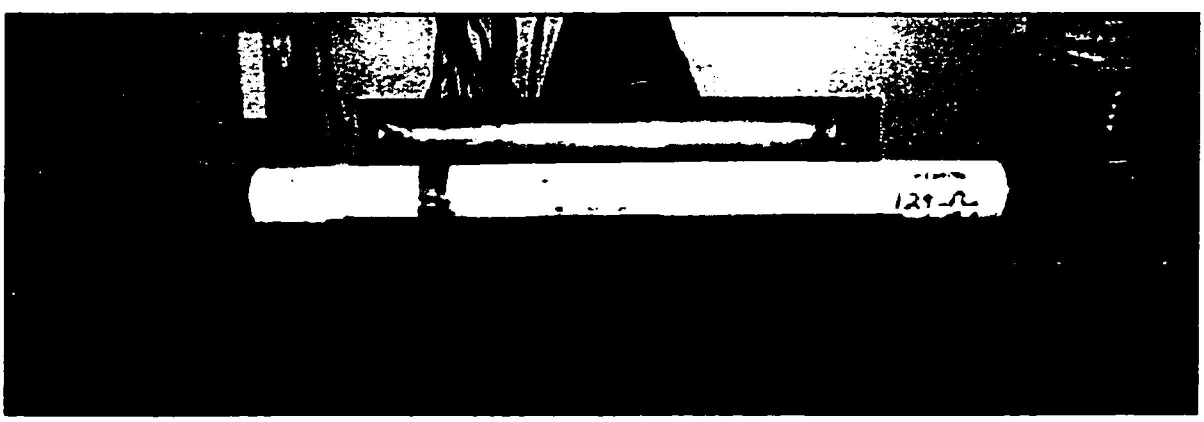

Figure 1. Folding Fin Aircraft Rocket

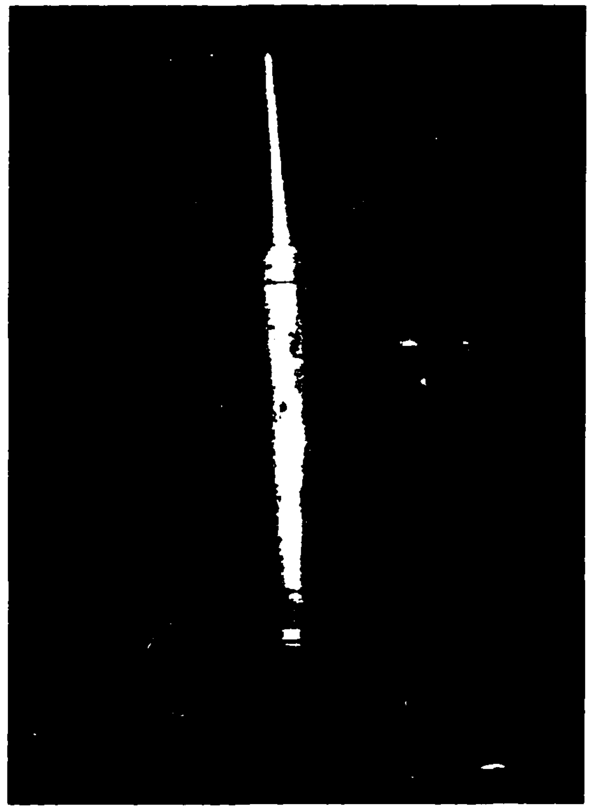

Figure 2. FFAR Nosecone and Flare

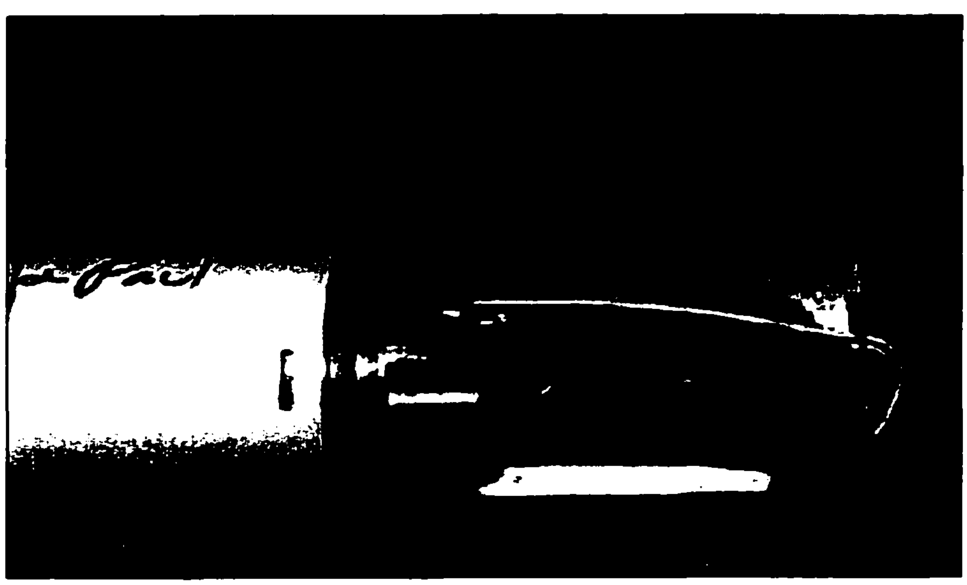

Figure 3. FFAR Fins in Folded Position

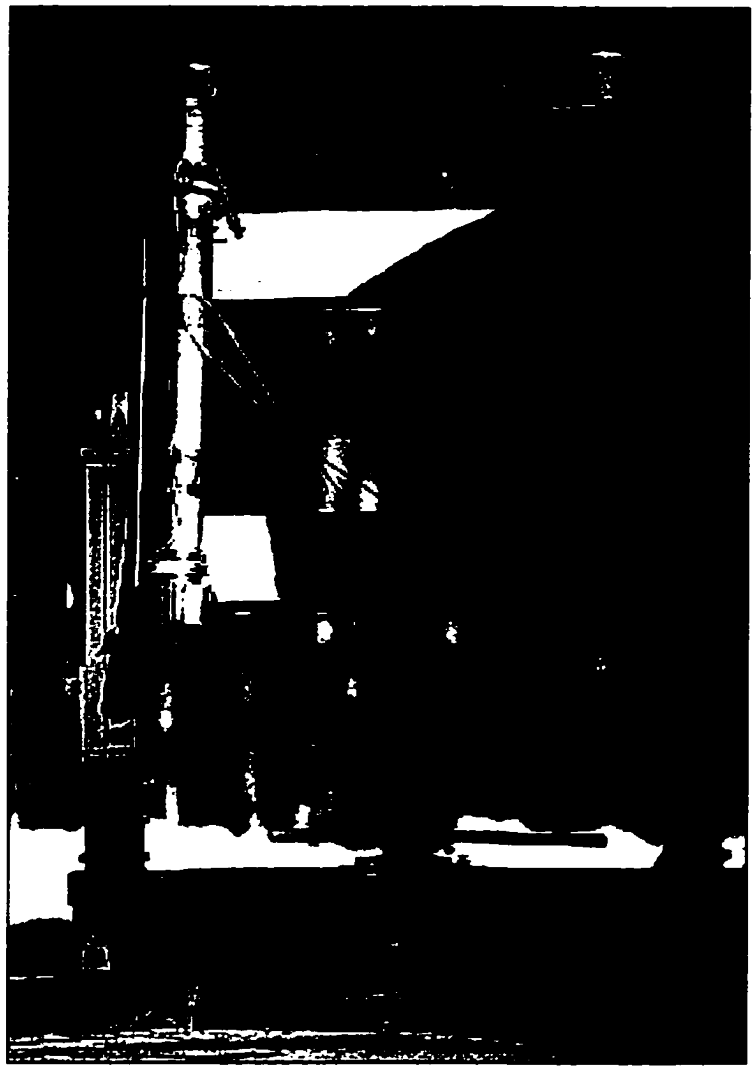

Figure 4. FFAR Cylindrical Launcher

2.2 FFAR Launch

The FFAR used for this thesis work was launched in February 1997 at Poker Flat Research Range in Fairbanks Alaska. The night of the launch I took measurements of the dimensions and weights of the rocket, as well as the outside air temperature (10 degree F). Other data collected was the wind direction and speed and the radar data of the FFAR in flight. Once the Wallops wind weighting team collected the wind data and the FFAR was loaded into the cylindrical launcher by the Poker Flat launch officer, the countdown began.

At T-2 seconds I pushed the red launch button so as to have the rocket, which has a two second delay in the igniter, leave the pad at T-0 seconds. Soon after launch the radar locked onto the FFAR, which was launched at 81 degree elevation and 0 degree azimuth, and started to collect the flight data. I then obtained both the wind and radar data the following day after it was printed, and had the opportunity to clarify my questions about any of the data with the Wallops launch team.

2.3 Wind Data

The wind data collected by the NASA Wallops Wind Weighting team is used to adjust the launcher settings, azimuth and elevation, so that the impact point stays the same as the no wind impact point. The wind data (Appendix A.1) which is typically collected within 2 hours of launch, is collected using two methods. The first method is by using anemometers fixed on a tower at the launch site, and the second method is by releasing a balloon at the launch site that has a reflective material attached to it. The balloon is then tracked and the wind speed and direction is collected for various altitudes. When combining both of these methods a wind table is created. This table shows the layer number (the number of the altitude), the wind velocity in ft/sec, the true wind direction (the direction the wind is coming from), the x and y components of the wind, and the boundary (the altitude in feet for each layer). The data given at each layer is the average wind speed and direction between that layer and the pervious layer. The first 13 data points have a T next to them indicating that they were collected by the anemometers while the other data was collected from the wind balloon.

2.4 Radar Data

The radar data (Appendix A.2) was collected by the NASA Wallops radar team. The method used to acquire or lock onto the rocket was through an MK-51 open site. The radar antenna was "slaved" in angles to the open site meaning the azimuth and elevation were positioned to where the open site pointed. The range was then set to some point the operator felt would put the target near the tracking gate when it flew through the radar beam. When the operator saw the target, he moved his range "gate" to the target, tracked it, and set the "Auto-track". In full Auto the track bit is set and an "*" is next to the time data point. The set range was determined through operator experience and wind weighting predictions. The Auto track started approximately 3.5 seconds after launch, however the altitude and velocity data from launch to Auto track is an estimation compiled from a combination of manual tracking and data reduction. The rocket data was collected at a rate of 10 HZ and the first auto track point is at a time of 070504.70 seconds, which made the launch time approximately 070501.00 seconds. The range, altitude, and velocity are not zero at this time due to the open site being set at a predetermined point, and the radar site is not located at the launch point. The "cu" in front of az, el, and rg refers to corrected unfiltered data. This data is corrected for radar mount mislevel and any encoder (az and el) biases. The data includes the time (seconds), rocket altitude (vertical distance above the ground in feet), the range (slant distance from the radar site to the rocket in yards), the target velocity (velocity of the FFAR in ft/sec), the azimuth and elevation of the FFAR (angles from the radar to the rocket in degrees), and S/N which is the signal to noise ratio.

3 Performance Prediction of FFAR

The prediction method used has been divided into three main sections: gravimetrics, aerodynamic coefficient calculation, and trajectory prediction. The gravimetrics include the motor burn, cg, and moments of inertia. These are needed in order to characterize the weight distribution, and size of the vehicle. The aerodynamic coefficients which include the drag, pitching moment, and normal force coefficients are dimensionless numbers which help characterize the vehicles stability, and its ability to damp out a disturbance. The last section, trajectory prediction, predicts an apogee and an impact point by using both the gravimetrics and aerodynamic coefficients in combination with trajectory equations. In addition, the main assumption for this prediction is that the rocket was a rigid body vehicle (no aeroelasticity).

3.1 Gravimetrics

3.1.1 Description

The initial analysis for the performance prediction of a FFAR was to calculate the c.g. location of the vehicle, the pitch-yaw moments of inertia (IYY, IZZ), and the radial moment of inertia (IXX). These calculations were compiled into one workbook as Excel spreadsheets, and all distances are measured from the Theoretical Nose Tip (TNT). The TNT is the location of the nosetip if it was brought to a point. This workbook allowed a change of weight or vehicle configuration in the first spreadsheet and automatically adjusted the c.g., IXX, IYY, and IZZ accordingly.

3.1.2 Center of Gravity

The first spreadsheet was created to calculate the c.g. of the rocket (Appendix C.1). This meant calculating the c.g. for the motor, fins, nosecone, and payload sections. The c.g. for the motor was the most difficult. The first step was to estimate the 10 degree F thrust curve by using the 165 and -65 degree F thrust curves along with the data sheets received from Navy Ordinance at Indian Head [24] (Appendix B.1). The estimate was made by following the general shape of the extreme temperature thrust curves in conjunction with plotting the few data points known for 10 degree F. The 10 degree F data points were interpolated from the FFAR data sheets. The data interpolated for the 10 degree F curve included the maximum thrust, average thrust, burn time, and action time. The action time being the time on the thrust-time record where thrust is continuously in excess of 150 lbf. The next step involved using propulsion data in conjunction with standard solid propulsion equations [8] [22] to compute how the motor c.g. changes with time. Some of the equations used were:

$r = ap^n$ where: r is the burn rate
a is a constant
p is the measured chamber pressure
n is the pressure exponent of the burning rate

$V_f = \frac{V_b}{V_c}$ where: V_f is the volumetric loading fraction

V_b is the propellant volume
V_c is the chamber volume

$b_f = \frac{b}{radius}$ where: b_f is the web fraction

b is the web thickness (grain thickness)
radius is the outer radius of the grain

Once the individual c.g's were computed the overall vehicle c.g. was calculated vs time. The next sheet in the workbook (Appendix C.2) summarizes the weight, length, and diameters for the vehicle.

3.1.3 Pitch-Yaw Moments of Inertia

The third sheet (Appendix C.3) has the standard equations for the longitudinal (pitch-yaw) moments of inertia for each section shape [5] [7] embedded into it. It is linked to the summary spreadsheet in order to acquire the appropriate weight and dimension for that section. The sheet also incorporates the parallel-axis theorem in order to compute overall IYY and IZZ for the vehicle. Some of the equations used are summarized in Table 2 (M=mass, R=radius, L=length, H=height). For the FFAR the pitch and yaw moments of inertia are the same for the vehicle (except the fins) due to the symmetry.

SECTION TYPE	SHAPE TYPE	IYY / IZZ
NOSECONE	SOLID CONE	$IYY = IZZ = \frac{3M}{80}\left(4R^2 + H^2\right)$
PAYLOAD	HOLLOW CYLINDER	$IYY = IZZ = \frac{M}{12}\left(6R^2 + H^2\right)$
FLARE	SOLID CYLINDER	$IYY = IZZ = \frac{M}{12}\left(3R^2 + H^2\right)$
MOTOR	HOLLOW CYLINDER w/ varying radius	$IYY = IZZ = \frac{M}{12}\left(6R^2 + H^2\right)$
FINS	FLAT PLATE	$IYY = \frac{MH^2}{12}$ $IZZ = \frac{M}{12}\left(L^2 + H^2\right)$

Table 2. Longitudinal Moments of Inertia

3.1.4 Radial Moments of Inertia

The last sheet in the workbook was designed to calculate the radial moments of inertia (Appendix C.4). As in the pitch-yaw spreadsheet it has the radial moment of inertia equations and the parallel-axis theorem embedded into it. Some of the equations used are summarized in Table 3.

SECTION TYPE	SHAPE TYPE	IXX
NOSECONE	SOLID CONE	$IXX = \frac{3}{10}MR^2$
PAYLOAD	HOLLOW CYLINDER	$IXX = MR^2$
FLARE	SOLID CYLINDER	$IXX = \frac{1}{2}MR^2$
MOTOR	HOLLOW CYLINDER w/ varying radius	$IXX = MR^2$
FINS	FLAT PLATE	$IXX = \frac{ML^2}{12}$

Table 3. Radial Moments of Inertia

3.2 Aerodynamic Coefficient Calculation

3.2.1 Rogers Aeroscience Rocket Performance Software

3.2.1.1 Description

The aerodynamic coefficient calculation started by needing an initial estimate of the velocity vs. altitude curve. This curve was needed in order to calculate the coefficients for a specific velocity and altitude (atmospheric conditions) at a point in the trajectory. This estimate was calculated using a program developed by Rogers Aeroscience in 1991. This program is broken down into sections and can perform many separate tasks. however. three main prediction sections are: motor. CD2. and ALT4. All three of these sections require data ranging from the nozzle exit area to the launch temperature.

3.2.1.2 Input Files

3.2.1.2.1 Motor

The first file developed was the motor file for the FFAR. The variables defined were the MK40 motor dimensions, and the thrust curve that was developed for the c.g. spreadsheet in section 3.1.2. The motor input file developed (Appendix D.1.1) for the MK40 motor could be used for any rocket utilizing the MK40.

3.2.1.2.2 CD2

The next input file created computed the drag coefficient of the rocket as a function of mach number. This file (Appendix D.1.2) includes the configuration of the rocket, fins and nosecone geometry's, as well as a general lug diameter. After running the CD2 file, the program displays the drag on each part of the rocket (Appendix D.2.1). This includes the fin drag, pressure drag, and lug drag. At this point the data should be checked for excess drag on an individual piece. Note: The FFAR has no lugs.

3.2.1.2.3 Alt4

ALT4 is the input file for altitude prediction which uses a 4th order Runge-Kutta numerical integration method. In this file (Appendix D.1.3) the motor file, drag file, and the initial flight conditions are defined. ALT4 also contains the option of running a single payload weight, or multi payload weights. For the single payload weight mode the user chooses a payload weight and the flight data is calculated. For the multi payload weight mode the user chooses a upper and lower payload weight, and an amount to increment the weight by. The output would then show the apogee for each payload weight. this method gives a good estimate of the optimum payload weight for a particular vehicle.

3.2.1.3 Output File

The output files (Appendix D.2.2.1 and D.2.2.2) for this program includes time (sec), mach number, thrust (lbf) (from the user input in the motor file), altitude (ft), and g-loads through apogee for a given rocket. For this program Rogers assumes a 90 degree launch elevation angle, therefore the altitude data should be multiplied by cos θ, θ being

90- (the launch elevation angle). This new altitude is a closer approximation to the vehicle altitude. As discussed above, the data used from this program is the altitudes vs. mach number curve. This data along with the vehicle c.g. calculated above will be used in the input file of the next program, USAF Stability and Control DATCOM. Rogers also has a plotting program named RPLOT (Appendix D.2.3). This plots the thrust, altitude, cd, and velocity as functions of time. This plot shows the general relationship between the variables, and allows the user to glance at the data and get a general feel for the apogee and maximum velocities the rocket will experience.

3.2.2 USAF Stability and Control DATCOM

3.2.2.1 Description

Missile DATCOM was originally developed by the McDonnell Douglas Astronautics Company under contract by the Air Force in the late 1970's. The fundamental purpose of Missile DATCOM is to provide an aerodynamic design tool which has the predictive accuracy suitable for preliminary design, and the capability for the user to easily substitute methods to fit specific applications. Missile DATCOM has many capabilities and restrictions in it, some of these include the number of fins that can be used and the body size and shape. All of the capabilities and restrictions are summarized in the users manual [23]. Some of the aerodynamic parameters DATCOM calculates are the normal force coefficient (CN), pitching moment coefficient (Cm), center of pressure (C.P.), axial force coefficient (Ca), Rolling moment coefficient (Cl), and the normal force coefficient derivative with angle of attack ($CN\alpha$). DATCOM also computes side force coefficient (Cy), yawing moment coefficient (Cn), the derivatives of these coefficients, and the magnus derivative. In addition DATCOM calculates the normal force coefficient due to pitch rate (CNQ), and the pitching moment coefficient due to pitch rate plus pitching moment coefficient due to rate of change of angle of attack (CMQ+CMAD). For elaborations regarding the above coefficients see reference [1].

3.2.2.2 Input File

The input file (FOR005.DAT) is shown in Appendix E.1. Inputs to Missile DATCOM are grouped by "case". Each "case" includes the set of input cards that define the flight conditions and geometry to be run. The main Namelists used were flight conditions ($FLTCON), reference quantities ($REFQ), axisymmetric body definition ($AXIBOD), and fin descriptions ($FINSETn). The users manual [23] describes in detail what should be in each Namelist. An example of the Namelist REFQ is listed below:

SREF = Reference Area
LATREF = Reference Length (lateral direction)
ROUGH = Surface Roughness Height (table for estimation is in user manual)
XCG = Longitudinal Position of C.G.
ZCG = Vertical Position of C.G.
BLAYER = Boundary Layer Type (Natural transition or fully turbulent)

Once all of the Namelists for the case are defined, the control card inputs need to be picked. Control cards are one line commands which select program options. Although they are not required, they permit user control over the output. The control cards used here are the DAMP card, CASEID card, and DIM IN card. These cards along with all the other options are again fully explained in the users manual [23]. The FFAR output included both the fin+body static coefficients (CN, Cm, Ca) and the dynamic coefficients (CNQ,CNAD). If the user wanted to see the aerodynamic coefficients for each component (fin, body, nose) a BUILD card could be used.

3.2.2.3 Output File

The output file (FOR006.DAT) for DATCOM is in Appendix E.2. The input file is included in the output, then the static aerodynamics and the dynamic coefficients follow. The FFAR input file was run approximately 20 times. Once for each altitude which included the corresponding mach number and cg for the vehicle. The spreadsheet (Appendix H.1) contains the summary of coefficients DATCOM generated. Included in the table is the mach number, altitude, and xcg used in DATCOM for the calculation of the coefficient. Each column heading explains from which source that data was taken.

3.3 Trajectory Prediction

3.3.1 Sens5d Trajectory / Wind-Sensitivity Calculations for Unguided Rockets

3.3.1.1 Description

Sens5d was prepared by Computer Sciences Corporation under contract by NASA Wallops Flight Center in 1975. Sens5d is a computational procedure which numerically integrates the equations of motion [3] [4] of an unguided rocket. Three translational and two angular (pitch and yaw) degrees of freedom are integrated through the final burnout, then only the three translational motions are considered through impact. The numerical integration procedure is a fourth order, modified Adams-Bashforth Predictor Corrector method. This method is supplemented by a fourth-order Runge-Kutta method to start the integration at t=0 and whenever error criteria demand a change in step size. Sens5d also includes wind weighting procedures. Wind weighting is the adjustment of the rocket launcher or impact parameters to accommodate for the prevailing winds. The usual practice is to simulate the total wind effect on the complete trajectory rather than evaluating the continuous wind response along the path. This is achieved by defining a "ballistic wind velocity" and a "unit wind effect", such that their product yields the effective displacement of the impact point due to the wind. Sens5d has the capability to calculate the wind weighting functions needed to evaluate ballistic wind and the unit wind effects. A number of assumptions are made in Sens5d, these include:

1. A five degree of freedom rigid body dynamics model from the first stage ignition to the last stage burnout. After the last burnout the program shifts to three degree of freedom point mass dynamics.
2. The program assumes linear aerodynamics (the coefficients are a function of mach number only).
4. Only a axially symmetric rocket can be considered, with no thrust or fin misalignment and no center of gravity deviation from the centerline of the rocket.
5. The program uses a rotating model and a 1962 standard atmosphere table.

The coordinate systems and transformations used are described fully in the users manual, along with the general aerodynamic equations and the equations of motion.

3.3.1.2 Input Files

The input for Sens5d is split into 2 data sets and has a wide range of flexibility for special calculations. One special calculation may include predicting the impact point of the discarded motor or ejected nosecone. Each of these items would be considered a spent stage. The method used for this prediction was to set the launch elevation and azimuth angles, then to predict the impact range and bearing. For this method the physical and aerodynamic characteristics of the rocket are known along with the wind profile, then the equations of motion are numerically integrated to achieve impact. The other method available is for a given impact range and bearing, one predicts the required launch elevation and azimuth. This method involves an iterative procedure and several trajectories may have to be integrated, which may or may not be convergent.

3.3.1.2.1 Data Set #1

Data set #1, (Appendix F.1.1) FORT.5, consists of four program control lists, DLIST, BLIST, FLIST, and ULIST. All of these control lists have default values which may or may not be used. The first list contains the initial values for the rocket, including the latitude and longitude of the launcher, initial time, altitude, and velocity, and also the step size and amount of error allowed during integration. The BLIST controls the option to calculate the burnout flight elevation, apogee, spent-stage impact, and payload impact range as a function of launch elevation angle and payload weight. The input includes the payload weight, and wind speeds and direction. The FLIST controls the option to calculate the wind weighting factor as a function of altitude. The data includes payload weight, launch angles, and wind data. The ULIST controls the option to calculate the coriolis deflections north and east, range derivatives, and unit wind effects for head, tail and crosswinds as a function of launch elevation angles. This input again includes payload weight, launch angles and wind data. For the FFAR trajectory prediction the wind data collected at the launch (Appendix A.1) was used in the BLIST, FLIST, and ULIST.

3.3.1.2.2 Data Set #2

Data set #2, (Appendix F.1.2) Fort.1, includes the aerodynamic tables, and starts with general block data, a title card, and information about any spent stages. It is then broken down into a series of phases. A new phase is required whenever a change in aerodynamics, vehicle geometry, or a step change in weight occurs. The data in each phase is entered in a specific order following the title card and general block data. The order of the data is:

1. Time for thrust and weight
2. Thrust
3. Expendable weight remaining in this stage
4. Mach number for drag coefficients
5. Drag coefficients
6. Time for gravimetrics
7. Distance from nose to center of gravity
8. Pitch moments of inertia
9. Mach number for pitch damping coefficients
10. Pitch damping coefficients
11. Mach number for slope of normal force coefficients
12. Slope of normal force coefficients
13. Mach number for center of pressure locations
14. Distance from nose to center of pressure

3.3.1.3 Output File

While the output (Appendix F.2) of Sens5d is geared mainly to the wind weighting procedure, it also provides a detailed trajectory as well as a summary of the trajectory at burnout, apogee, and impact. It also provides a summary of the spent stage trajectories, unit wind effects for head, tail and cross winds, and coriolis deflections. Sens5d output is mainly used in the flight and ground safety reports which include the wind limits for launch along with the launch azimuth and elevation. In this thesis the Sens5d trajectory prediction was compared to the FFAR flight data.

3.3. LRC-MASS (GEM)

3.3.2.1 Description

The LRC-MASS (GEM) computer program was originally written by the General Electric Company under contract to the Manned Spacecraft Center. Since then many modifications and changes were made to the program by various agencies and groups at NASA- Langley Research Center. The abstract for LRC-MASS (GEM) [21] reads as follows:

> "This is a multi-phase trajectory program with optional simulation capabilities which include a general three-dimensional package, a general two-dimensional package, and a multi-vehicle package. These packages range in complexity from a two-dimensional particle simulation up to a full six-degree of freedom simulation."

By using LRC-MASS (GEM) program a six-degree of freedom (DOF) trajectory analysis for certain phases of the flight was performed. This included the initial thrusting phase and the coasting to apogee phase, however the run time for the program is considerably longer when it is used in the coasting phase. The main focus when using LRC-MASS (GEM) was to determine the overall dynamic characteristics and stability of the rocket including the amount of pitch-roll coupling and the coning angles [14] throughout the trajectory. The program has many advantages ranging from incorporating spin rates to adding a thrust misalignment or offset c.g. The LRC-MASS (GEM) trajectory prediction was used for the comparison of velocity, altitude, and range to the FFAR flight data.

3.3.2.2 Input File

One of the LRC-MASS (GEM) input files created is in Appendix G.1. When starting the input file the first step was to decide how many phases to break up the flight into. Some examples may be: thrusting, coasting, under drogue chute, under main chute, etc. The next step was to decide how many DOF to run for each phase. For the FFAR a 6DOF trajectory program was run for the thrusting and coasting to apogee phase, then a

3DOF particle trajectory program was run for the remaining phase of the flight. The 6DOF trajectory program computes the translational and rotational motion of a rigid body in three-dimensional space. The angular velocity of the body is computed from the moments on the vehicle. The 3DOF particle trajectory program computes the translational motion of a point in three-dimensional space. The next option available is to chose a mode of operation. Three modes are available; normal, parametric, and boundary-value mode. For the FFAR analysis the normal mode was chosen. This mode instructs the program to read data from the input device, integrate the equations of motion to a specified end condition, and return to read more data. The other two choices are defined in the user manual [21].

The input file can be separated into blocks, where each block serves a distinct function. The blocks used in the normal mode were: System Control Cards, Subroutines to be changed, CT-array, Tabular Input, and "Case" Inputs, in addition to these a "Second Job" Inputs block could be used if plotting is desired.

The first and second block, System Control Cards and Subroutine to be changed, are necessary to run the LRC-MASS (GEM) program. These blocks include the basics of the program and only need to be changed when subroutine replacements are desired.

The third block, CT-array, contains physical constants, conversion factors, and structures of the transformation matrices. This block contains many choices, including linear or nonlinear aerodynamics, c.g. offset, fin misalignments, roll rates, and body angular rates.

The fourth block, tabular input, is used when data tables are to be used. This may include data tables for thrust vs time, mach number vs. aerodynamics coefficients, or a three way table of drag coefficient, mach number, and altitude.

The fifth block, "case" inputs, includes the initial conditions (initial time and altitude), optional calculations (spin/no spin), termination conditions (when to stop calculations), and output formats. Following this are the table control cards which instruct the program how the data tables are to be used.

The format for all of these blocks is detailed in the LRC-MASS (GEM) users manual [21].

3.3.2.3 Output Files

LRC-MASS (GEM) output variables are determined by the user in the input file. The output file format is as follows: program name, run time and date, user name, input file, output data. For the FFAR output file (Appendix G.2) the time in seconds and altitude in feet are given for each phase of the flight. If a different output variable is desired the user may change the output specifications in the input file and rerun the program.

4 Results

4.1 Trajectory Comparison

After completing the prediction process, an iterative improvement process began. The values of velocity, coning, etc. output by LRC-MASS (GEM) were used in the input of DATCOM and rerun. For example: the coning angle was used as an angle of attack. These new values from DATCOM were then used to rerun Sens5d and LRC-MASS (GEM). This process continued until the output from one trajectory run to the next showed very little difference. At this point a trajectory comparison was made. The two trajectory values compared were the apogee and impact point of the rocket. For different reasons both of these quantities are equally important . Apogee accuracy is important if separation or parachute deployment is planned for this point, and impact point accuracy is important for range safety. The comparison was made between the radar flight data and the predicted wind weighted Sens5d and LRC-MASS (GEM) trajectories. The first step was to alter the radar flight data so it could be compared to the predicted data. This meant using trigonometry to change the radar data reference point from the radar site to the launch site. The radar site was approximately 1028 ft at 168 degree (from north) from the launch point. The difference in elevation of these two sites was 19.6 feet. For the first variable, velocity, very little was adjusted. The values of velocity before the Auto-track was initiated had the value 28.1 ft/sec subtracted so as to zero out the launch point. The points after the Auto track are not altered since the radar was tracking the vehicle velocity directly. For the next variable, altitude, all data before Auto track have 770.6 ft subtracted so as to bring the launch point to 647.4 ft ASL, which is the altitude of the launch site ASL. For all data after Auto track, nothing was adjusted since it was measured directly ASL. The last variable adjusted was the range. The range was adjusted by using trigonometry and from knowing the distance from the radar site to the launch point.

4.1.1 Apogee Comparison

For apogee, three variables were compared: altitude of apogee, time to apogee, and velocity at apogee. The altitude comparison (Figure 5) shows the actual apogee to be 16906 ft, while the predicted apogee was 14989 ft and 14381 ft for Sens5d and LRC-MASS (GEM) respectively. This gives a maximum error of 15%. The main source of error in altitude is due to the modeling of the flap on the fins. The frontal area of one fin without the flap was .519 in^2, and when adding the flap frontal area to this, the total is 1.14 in^2. This is an increase of 54% to the frontal area of the each fin. This increase would increase the fin drag which is the main contributing factor to the overall drag (fin drag=.662, total drag=1.046). The flap for this prediction was not only modeled as frontal area but it was modeled as frontal area with no spin. This frontal area in general was over estimated and would have been reduced even more if spin was incorporated in the calculation. The spin would have changed the oncoming flow angle which in turn would have reduced the frontal area of the fin. This change of angle (Figure 6) is between .4-.5 degrees throughout the flight. Since the frontal area would be less, the drag coefficient calculated would also decrease, hence the predicted altitude would have increased. The drag coefficient may decrease from 2.3 to 2.1 with a 1% decrease in frontal area for high mach numbers. Error may have also accumulated from the estimation of the spin rate. The spin rate curve was initially estimated from FFAR data sheets (Appendix B.1) which gave a burnout spin rate of 17.5 cps and the scarfed nozzle contribution was estimated at 1 cps, from the performance data book [24]. If the rotation rate was estimated too high in the prediction then the predicted apogee altitude would be lower due to the amount of rotational kinetic energy that was used up for the extra rotation of the rocket. This rotation rate estimation error could be reduced if the spin rate generated by LRC-MASS (GEM) was used in the iteration process.

The next apogee comparison is in the time it takes to reach apogee. From Figure 5 the time to apogee is 27.8 seconds for the FFAR flight, 28.44 seconds for Sens5d and 25 seconds for the LRC-MASS (GEM) prediction. The 10% error here may result from the same sources as the altitude error above.

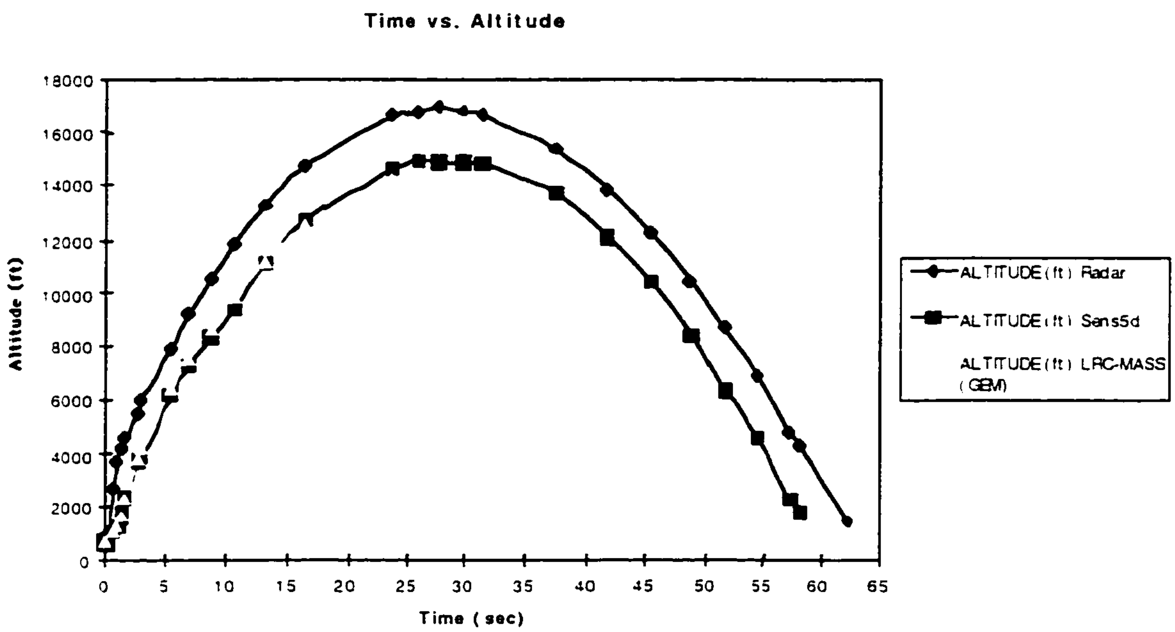

Figure 5. Time vs. Altitude: Radar, Sens5d, LRC-MASS (GEM)

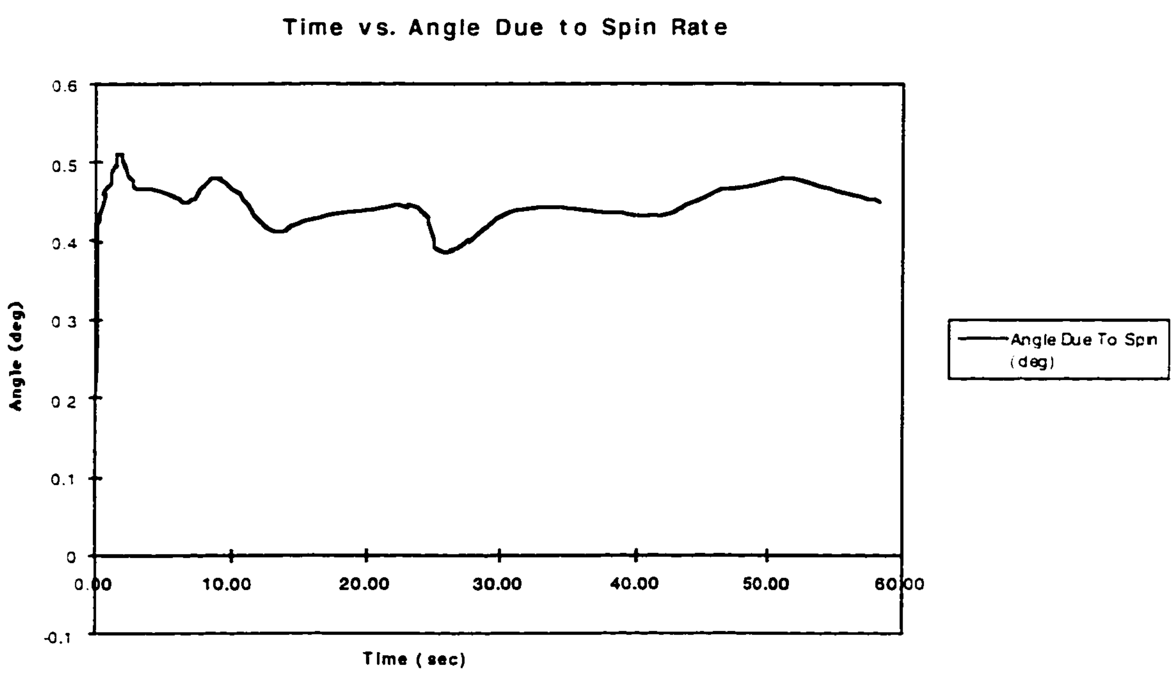

Figure 6. Time vs. Fin Frontal Area Decrease Angle Due to Spin Rate

The last apogee comparison was of the total velocity of the FFAR. The predicted velocity at apogee from Figure 7 can be seen to be up to 60% lower than the actual velocity. This error may again be due to the over estimation of drag, spin rate estimation, and energy loss due to rotation. However, as Figure 7 shows, the burnout velocity for the FFAR flight (1462 ft/sec) and the two predictions (Sens5d: 1615 ft/sec and LRC-MASS (GEM): 1520 ft/sec) match very closely. The difference is only 4% when predicting with LRC-MASS (GEM) and is 9% for Sens5d. This error may in part result from the age of the rocket grain. With age the grain degrades and shrinks which results in a lower impulse. If the impulse is lower the burnout velocity is also lower, this would explain why the actual burnout velocity is lower than the predicted. This burnout velocity is important in determining the maximum g-loads of the vehicle in flight.

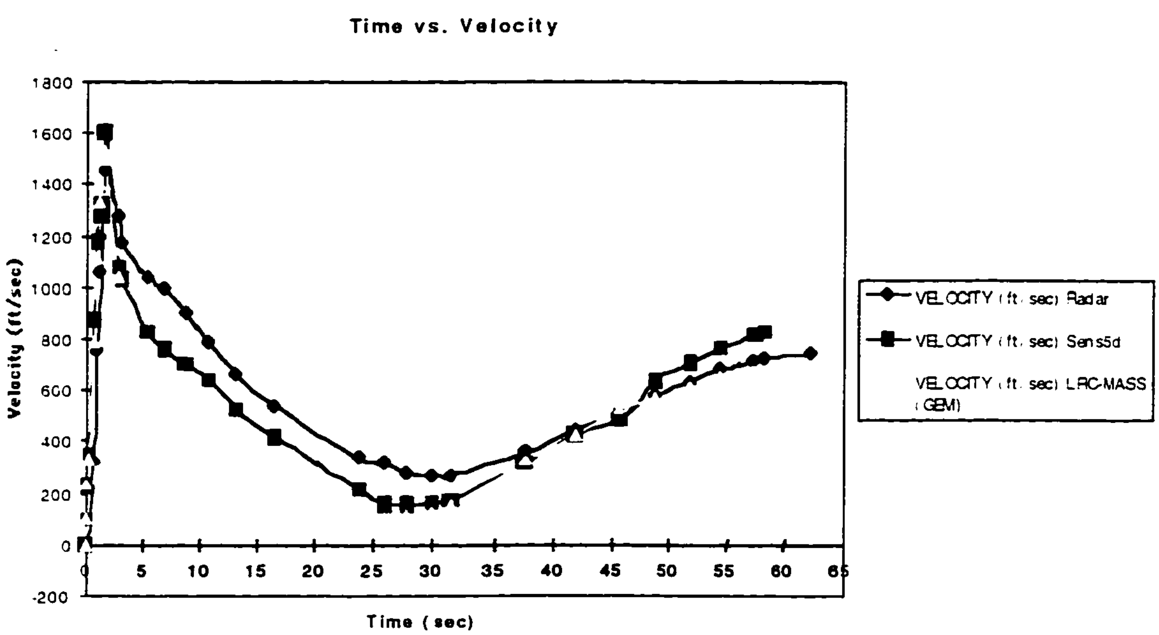

Figure 7. Time vs. Velocity: Radar, Sens5d, LRC-MASS (GEM)

4.1.2 Impact Point Comparison

The next trajectory comparison was of the rocket impact point. This included the range, azimuth, and time to impact. Table 4 shows this comparison between the radar, Sens5d, and LRC-MASS (GEM) data. The radar tracked the rocket to an impact point of 15414 ft with a 6 degree azimuth from the launch point. The predicted impact was 8507 ft with 7 degree azimuth, and 5900 ft with a 5 degree azimuth when predicting with Sens5d and LRC-MASS (GEM), respectively. The error for the range is 60% if using LRC-MASS (GEM) and 45% if predicting with Sens5d. By using trigonometry the distance between impact points can be found. The distance between actual impact and Sens5d impact was 6910 ft, while the distance between actual impact and LRC-MASS (GEM) impact was 9516 ft. The acceptable dispersion or distance between predicted impact and actual impact is represented by three sigma. Three sigma is the radius of a circle around the predicted impact point for which actual impact is required to be within. This circle must be fully contained in the Poker Flat Research Range boundaries and not include any protected areas. Protected areas include as a minimum, all manned locations. For any range the FFAR has a sigma = .324 NM, and a three sigma would equal 5906 ft. If predicting with either LRC-MASS (GEM) or Sens5d then the actual impact would not fall in this dispersion range. Sigma is determined by developing a nominal (no wind) impact prediction, then by adding one misalignment (fin, thrust, tip off) a new impact point is determined. After adding more misalignments, sigma will equal the largest distance between impact points.

The error here for the impact range is very large. This error was suspected to come from the overestimation of the fin drag coefficient. In order to roughly see how much this drag coefficient changed the trajectory, a number of cases were run using Sens5d. Table 5 summarizes the outcome. The table shows that the reduction of the fin drag coefficient will add some distance to the range, and it will also bring the predicted apogee closer to the actual. However this Table also shows that the fin drag was not the only factor in the error since the predicted and actual ranges are still not equal.

Another possible error in the prediction method might be from the fact that the wind speed and direction was input for every 4000 feet up to 80,000 feet. The wind for the other altitudes were then interpolated by the computer program. This however was not a very accurate wind profile since the FFAR went to 17000 ft. If instead, the wind profile was as detailed as possible (using all of the data collected by the wind weighting team) for the altitude range of ground level to 20000 ft. then the range prediction error was reduced significantly (Table 6). This suggests that the range error was from the over estimation of the fin drag coefficient and the poorly resolved wind profile used in the prediction. Table 7 shows the predictions for a detailed wind profile and a 30% reduction in the fin drag coefficient. From Table 7 the range prediction for Sens5d is 13163 ft. and for LRC-MASS (GEM) is 11270. This gives the distance between predicted and actual impact to be 2265 ft when using Sens5d and 4151 ft when predicting with LRC-MASS (GEM). The actual impact is now within 3 sigma of the predicted impact point when using either program. Table 7 also shows that the apogee variables as well as the impact variables are much closer if using this model.

For the time to impact comparison. Table 7 shows that the maximum difference in time is 1.5 seconds. The lower predicted time follows from the lower apogee and shorter range.

Source	Range (feet)	Azimuth (degrees)	Time (seconds)
Radar	15414	6	63
Sens5d	8507	7	60.2
LRC-MASS (GEM)	5900	5	58.5

Table 4. Range comparison

Source % fin drag reduced	Apogee Altitude (ft)	Apogee Time (sec)	Apogee Velocity (ft/sec)	Impact Range (ft)	Impact Time (sec)	Impact Azimuth (deg)
Radar	16906	27.8	269	15414	63	6
Sens5d	14989	28.44	138	8507	60.2	7
Sens5d 10% reduction	15537	29	142	8810	61.3	6.9
Sens5d 20% reduction	16178	29.6	145	9418	62.5	7
Sens5d 30% reduction	16937	30	150	10026	63	7.2
Sens5d 40% reduction	17874	31	154	10633	65	7.25

Table 5. Drag Coefficient Reduction Effects

Source	Impact Range (ft)	Impact Time (sec)	Impact Azimuth (deg)
Radar	15414	63	6
Sens5d	10462	62.8	7
LRC-MASS (GEM)	8157	60.3	5

Table 6. Detailed Wind Profile Effects

Source	Apogee Altitude (ft)	Apogee Time (sec)	Apogee Velocity (ft/sec)	Impact Range (ft)	Impact Time (sec)	Impact Azimuth (deg)
Radar	16906	27.8	269	15414	63	6
Sens5d	16962	30.5	151	13163	64.2	7.3
LRC-MASS (GEM)	16492	26.9	130	11270	61.5	5.1

Table 7. Final Comparison

4.2 Performance

In addition to the above comparisons an overall stability analysis for the FFAR was developed from the output of LRC-MASS (GEM).

The stability of the rocket is defined as the tendency of the vehicle to return to its equilibrium after it has been disturbed. Disturbances may be in the form of wind gusts, wind gradients, turbulent air, tip off, or chuffing of the motor. Stability is broken down into two categories, static and dynamic. Static stability is the initial tendency of the vehicle to develop a restoring force and/or moment which tends to bring the vehicle back to the equilibrium condition after a disturbance. An equilibrium point here is defined as having the resultant force as well as the resultant moment about the c.g. being equal to zero. One measure of static stability is by the distance between the center-of-gravity (Xcg) and the aerodynamic center- of-pressure (Xcp), each being measured from the nosetip. When this quantity is divided by the reference diameter (usually the maximum diameter of the rocket) it is called the static margin (SM). For static stability at any angle of attack, the aerodynamic forces acting through the Xcp will create a restoring moment about the Xcg. Therefore, the Xcp should lie aft the Xcg for a statically stable rocket, hence the SM should be negative. In addition, the pitching moment coefficient (Cm) and its slope ($Cm\alpha$) are both a measure of the static stability of the vehicle [14] [16]. The Cm y-intercept should be positive and Cm vs alpha graph should have a negative slope to produce the correct restoring moment for a statically stable vehicle. The general equation for $Cm\alpha$ is [$Cm\alpha$ =

CNα (SM)]. This static analysis is for the longitudinal direction. Two other requirements for static stability are in the lateral direction and the rolling motion, which include yawing moment coefficients, roll driving, and roll damping coefficients.

For the FFAR Figure 8 and 9 graph the cp and cg distance from the nosetip respectively. Figure 10 graphs the SM of the vehicle. Figure 11 graphs Cmα, and Figure 12 graphs CNα. The graphs show that the SM, and Cmα are negative throughout the flight, and therefore both of the longitudinal static stability criteria are satisfied.

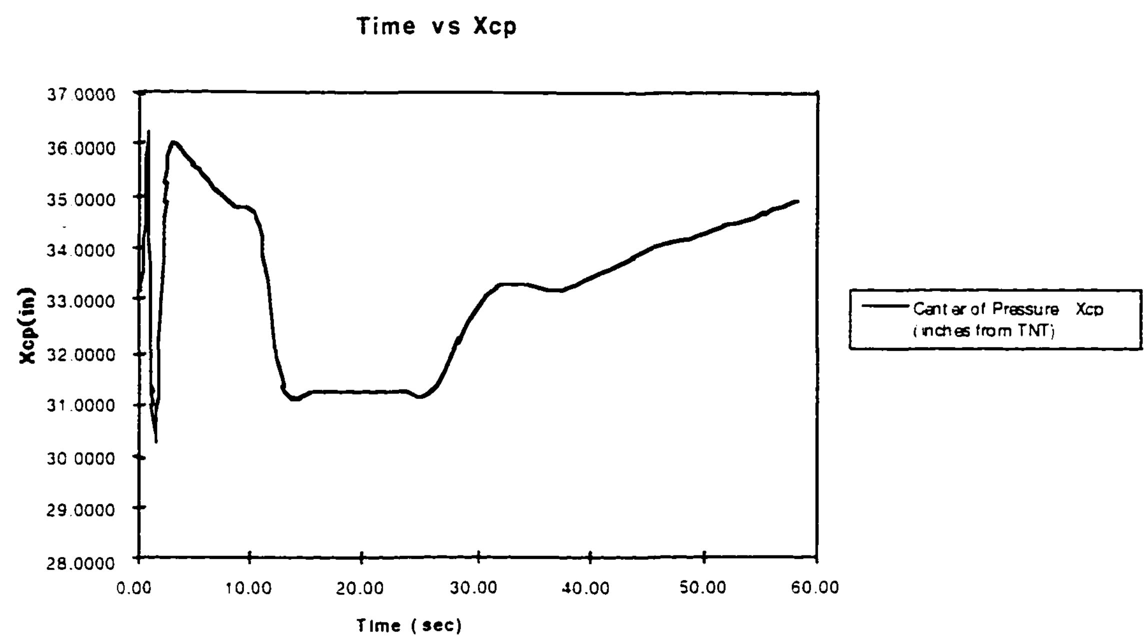

Figure 8. Time vs. Center of Pressure

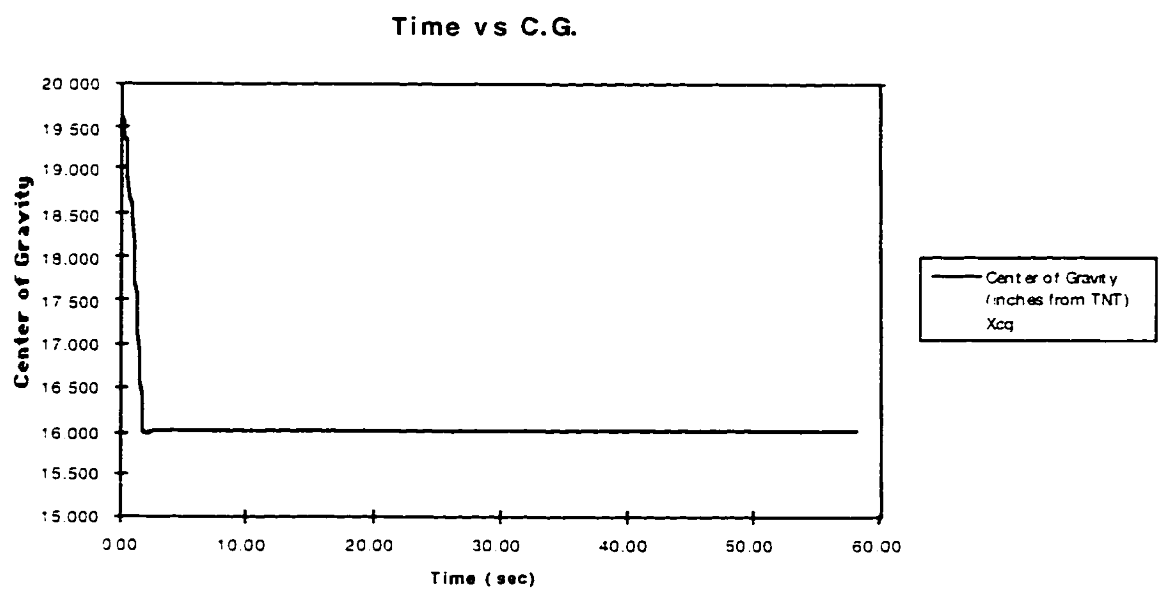

Figure 9. Time vs Longitudinal Center of Gravity

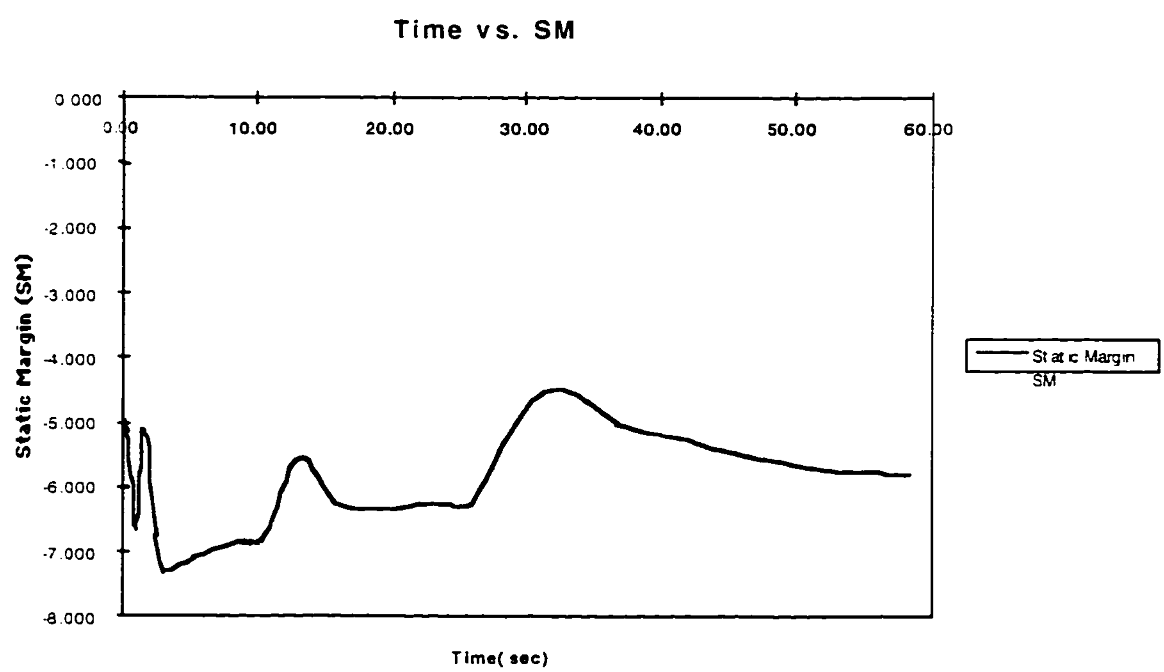

Figure 10. Time vs. Static Margin

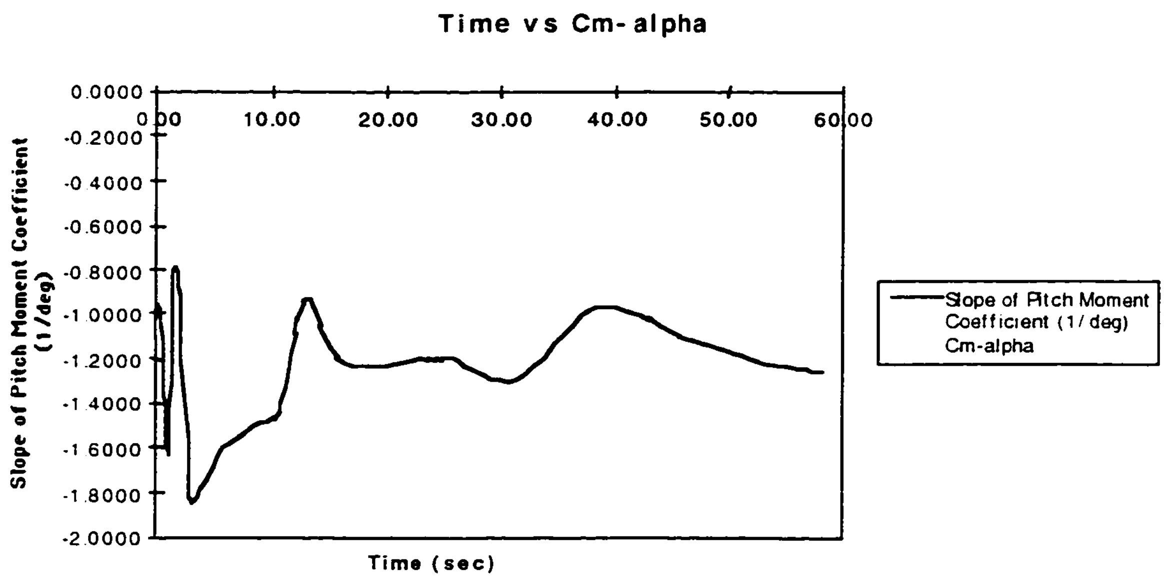

Figure 11. Time vs. Slope of Pitch Moment Coefficient

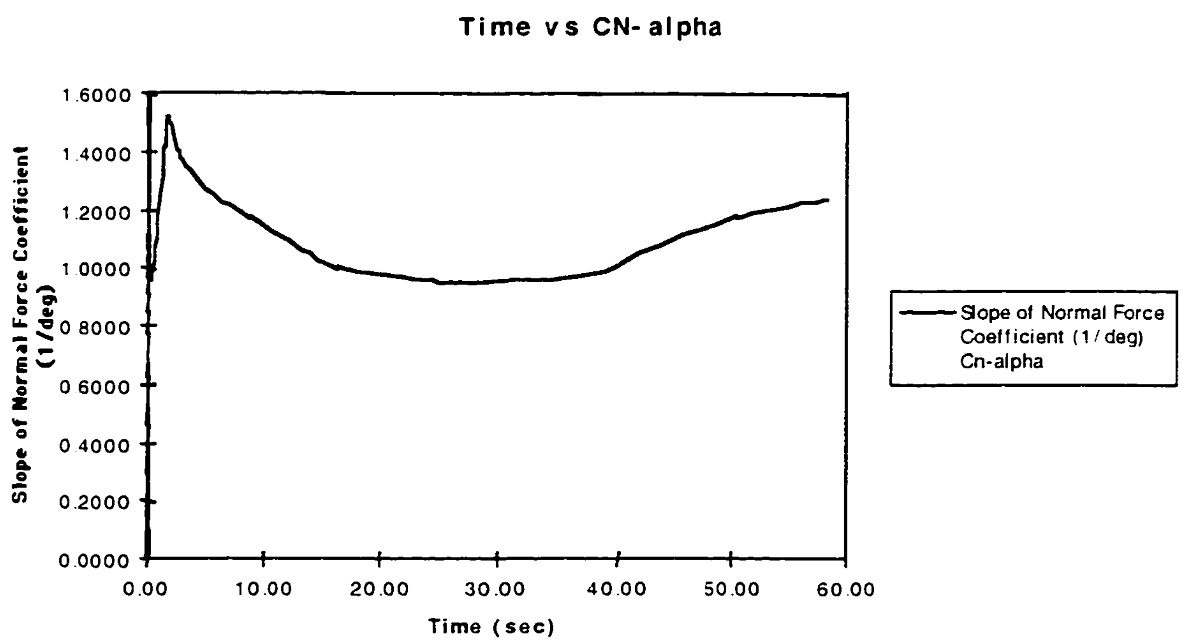

Figure 12. Time vs. Slope of Normal Force Coefficient

When analyzing the dynamic stability, the time history of the motion of the vehicle after it was disturbed from its equilibrium point is looked at. A dynamically stable rocket will have positive damping which is the dissipation of energy from a disturbance, or that the forces and moments will oppose the motion of the vehicle and cause the disturbance to damp out with time. Some of the flight conditions and disturbances that must be damped out are roll pitch resonance, wind gusts, and the coning motion of the rocket. Aerodynamic damping can be defined by Cmq [14] which is the pitch damping moment coefficient (Figure 13).

Damping can also be expresses in terms of a damping ratio ($\xi = \dfrac{-C_{m\alpha}qsd}{2\sqrt{-C_{m_q}qsd(IYY)}}$). This ratio determines for how many cycles the pitching oscillations of the rocket will persist. The optimum damping would be ζ=.7071 [11]. For underdamping ζ<.7071, and as ζ approaches zero the amplitude of the response to a disturbance increases and approaches infinity at ζ=0. This behavior is known as resonance. For overdamping ζ>.7071 and there is very little response to a disturbance, however the damping of that response is very slow. For the FFAR, Figure 14 shows ζ ranges from .02 to 20.09, and passes through resonance very rapidly (less than 1 second), therefore it is sufficiently damped.

Another stability issue is roll-pitch resonance. Roll-pitch resonance is defined as the point when the roll rate equals the natural pitching frequency and is considered locked-in when this condition is maintained throughout the flight. For a more stable vehicle (larger SM) the natural pitch frequency ($w_n = \sqrt{\dfrac{-C_{m\alpha}qsd}{IYY}}$) is higher, which then delays the start of roll pitch resonance. This delay is due to the higher natural pitching frequency crossing the roll rate at a later time. Figure 15 shows the natural pitching frequency and roll rate curves. These curves cross at approximately .05 seconds, and then continue in separate directions at different slopes. This is the trend for a stable vehicle.

Another aspect of dynamic behavior is the vehicle coning motion (Figure 16). Coning motion is when the vehicle spins about a spin axis and not about its geometric or principle axis, and uses the vehicle center of gravity as the apex. The coning motion is produced by roll-pitch resonance, and by spinning a vehicle which is out of balance. This coning motion increases the frontal area of the vehicle which in turn increases the drag coefficient. For the FFAR, Figure 16 shows the largest coning angle to be 14 degrees with the coning angle above 10 degrees for about 12 seconds. This angle is comparable to the aerobee 150 which has a maximum coning angle of 17 degrees. However, the coning motion of a vehicle should always be minimized. When reviewing Figure 13, 14, 15, and 16 the FFAR satisfies the above dynamic stability criteria.

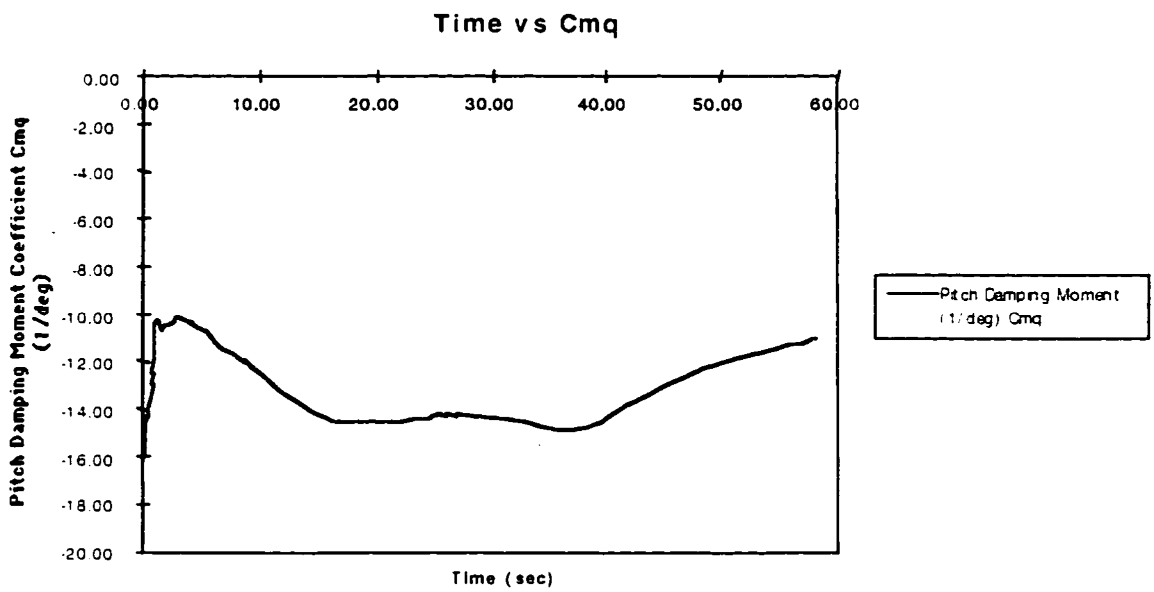

Figure 13. Time vs. Pitch Damping Moment

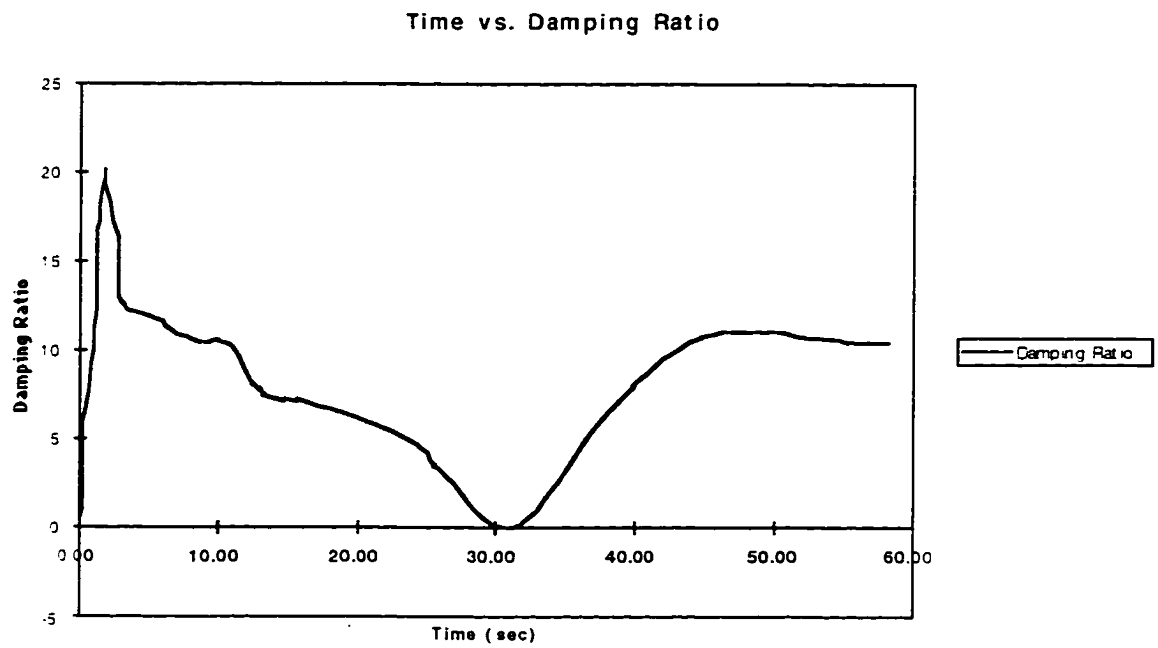

Figure 14. Time vs. Damping Ratio

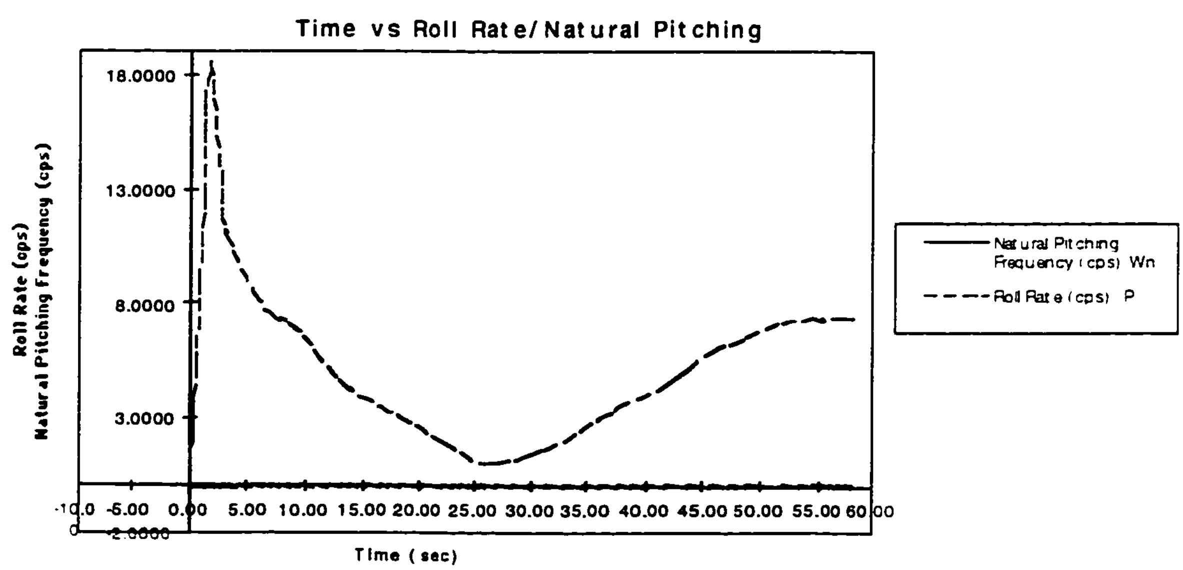

Figure 15. Time vs. Natural Pitching Frequency and Roll Rate

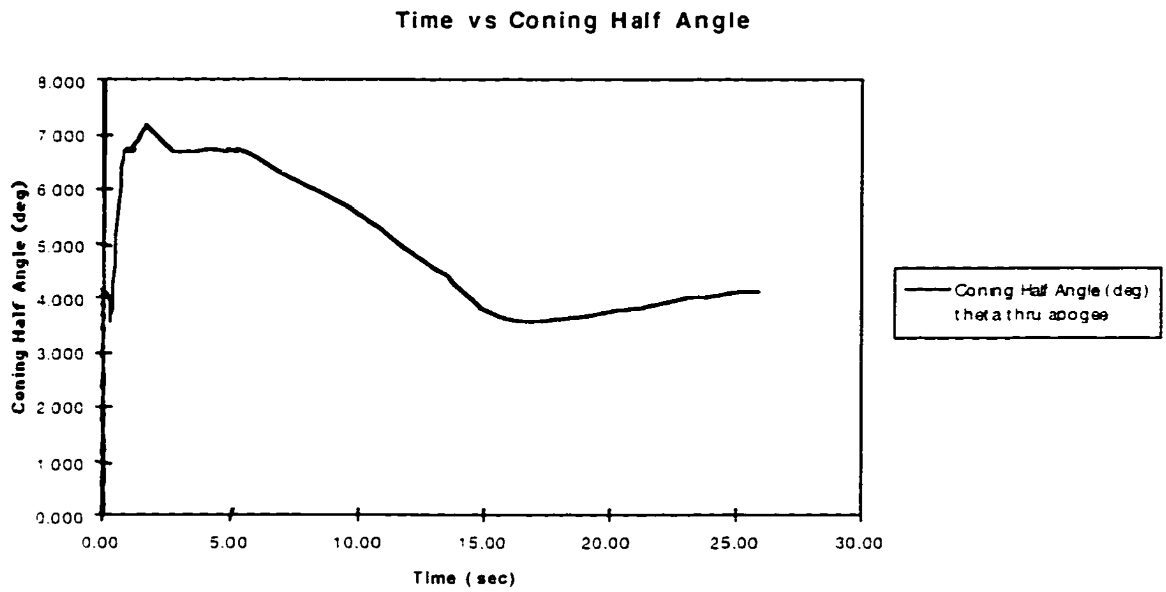

Figure 16. Time vs Coning Half-Angle

Both the mass properties and drag coefficient are important factors in the performance of the vehicle. The moments of inertia help determine the natural pitching frequency and coning rates, and high drag coefficients will degrade the apogee of the flight. Figure 17 and 18 show the longitudinal (pitch-yaw) and radial moments of inertia and Figure 19 shows the drag coefficients for the FFAR flight trajectory. Figure 19 displays a peak in drag which is due to the vehicle passing through mach one and that the coning angle at this time is large. This high coning angle increases the frontal area, which in turn increases the drag coefficient.

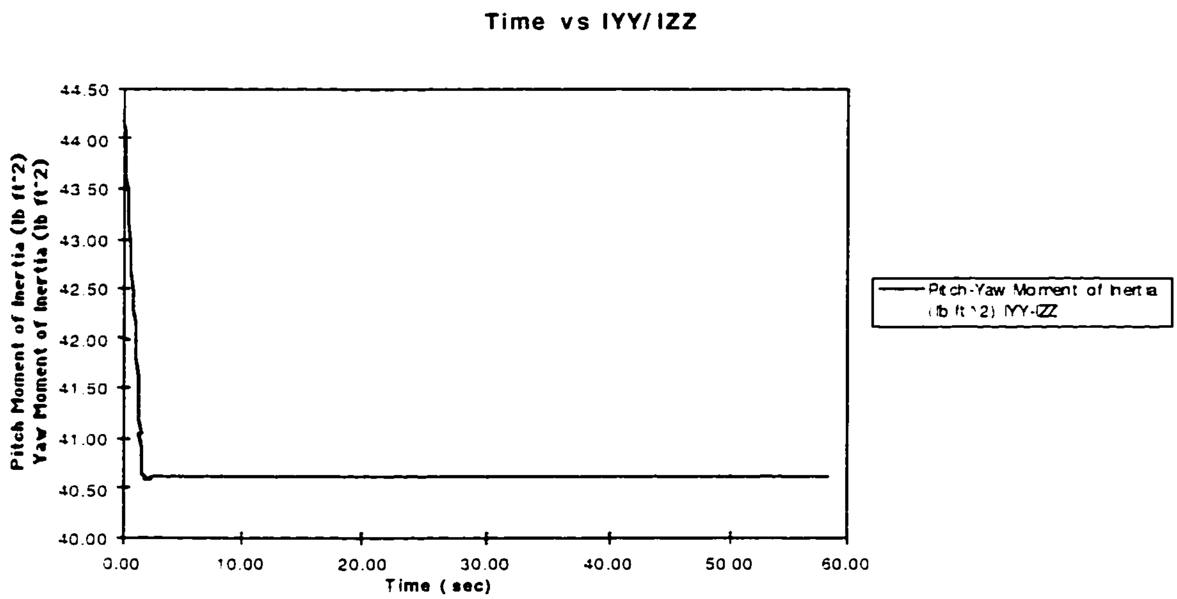

Figure 17. Time vs. Longitudinal (Pitch-Yaw) Moment of Inertia

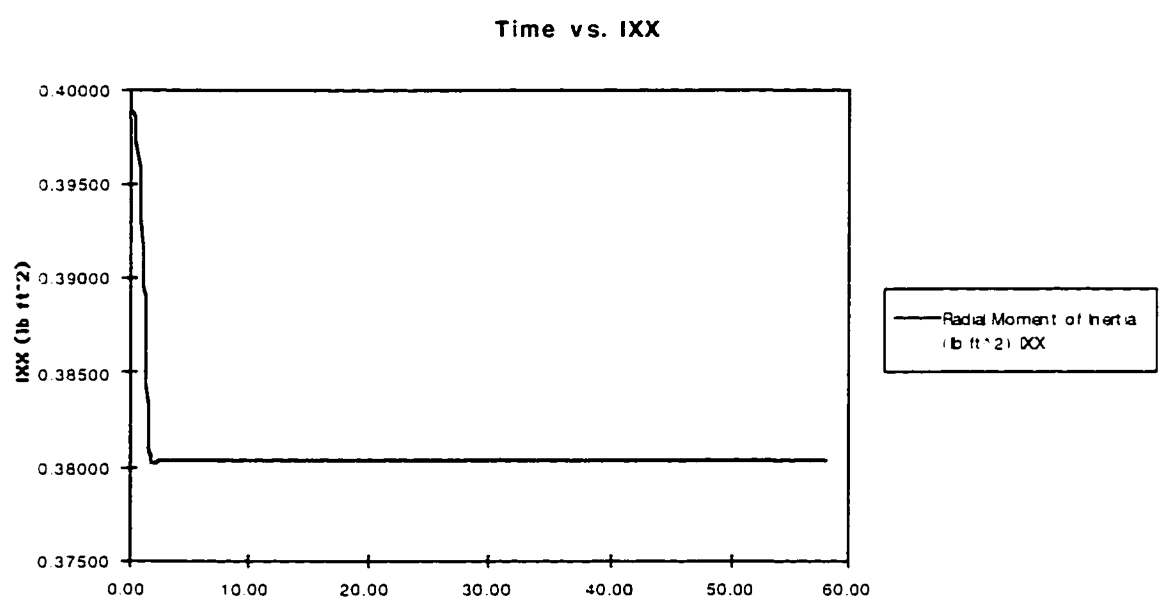

Figure 18. Time vs. Radial Moment of Inertia

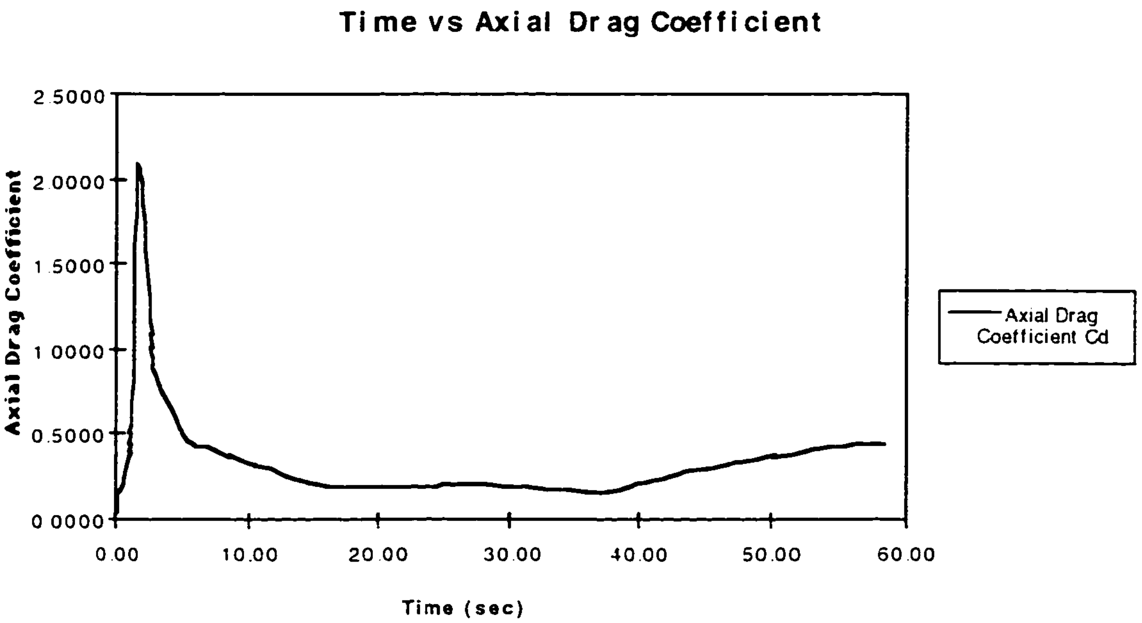

Figure 19. Time vs. Axial Drag Coefficient

5 Conclusions and Suggestions For Further Studies

5.1 Conclusions

The prediction methods used in this study show good agreement between the predicted altitude, range, and burnout velocity of the vehicle and the flight data. However, errors may accumulate from the following places. First, the estimation of the burn radius and in turn the estimation of the movement of the motor c.g. Second, over estimating the fin drag from the frontal area of the fin flap. Third, neglecting the aeroelasticity effects of the vehicle. Fourth, the estimation of the spin rate during the flight.

5.2 Suggestions for Further Studies

There are a number of ways to improve this method of performance prediction. One improvement would be to implement the TAD II Computer Program for Computing the Aerodynamic Derivatives of Sounding Rocket Vehicles. This program would compute the aerodynamic coefficients including a roll driving and damping coefficient. This would reduce the human error factor in hand calculating them. Another improvement would be to implement the optional subroutines Radar Calculations and Frequency Analysis in the LRC-MASS (GEM) program. The radar calculation option would determine the position and velocity of the vehicle with reference to a radar station instead of the launch point. Again, this would reduce the possibility of human error in adjusting the data to reference another point. The frequency analysis option would calculate the frequency and damping rate components of the nutational and precessional vector arms. This would help in forming a complete profile of exactly where and for how long in a given trajectory the coning occurs. The third improvement would be to study the aeroelasticity (bending moments) of the vehicle throughout the flight. The aeroelasticity becomes an issue as the length to diameter ratio grows. This means that for a very long slender vehicle the aeroelasticity will have an affect on the trajectory and performance.

APPENDIX A: FFAR Flight Data

A.1 Wind Data

W I N D   T A B L E   21:13:52

LAYERS 76   MAXALT 300000.00

LV	P	TRK	VEL	DIR	X-COMP	Y-COMP	BOUNDARY	FLG	POS1	POS2
1	t	0	3.70	50.70	2.86	2.34	0.00	1	.0000	.0000
2	t	0	3.70	50.70	2.86	2.34	647.41	1	.0000	.0000
3	t	0	3.70	50.70	2.86	2.34	680.11	1	.0000	.0000
4	t	0	6.95	57.15	5.84	3.77	695.11	1	.0000	.0000
5	t	0	10.20	63.60	9.14	4.54	710.11	1	.0000	.0000
6	t	0	11.65	65.00	10.56	4.92	730.11	1	.0000	.0000
7	t	0	13.10	66.40	12.00	5.24	750.11	1	.0000	.0000
8	t	0	13.25	66.50	12.15	5.28	775.11	1	.0000	.0000
9	t	0	13.40	66.60	12.30	5.32	800.11	1	.0000	.0000
10	t	0	14.40	66.25	13.18	5.80	825.11	1	.0000	.0000
11	t	0	15.40	65.90	14.06	6.29	850.11	1	.0000	.0000
12	t	0	16.65	61.55	14.64	7.93	882.61	1	.0000	.0000
13	t	0	17.90	57.20	15.05	9.70	915.11	1	.0000	.0000
14		7	22.13	77.70	21.63	4.71	947.41	1	1663.	-235.
15		7	26.47	76.49	25.74	6.18	997.41	1	1567.	-256.
16		7	25.46	72.98	24.35	7.45	1047.41	1	1475.	-282.
17		7	21.59	63.91	19.39	9.49	1097.41	1	1397.	-313.
18		7	23.33	59.44	20.09	11.86	1147.41	1	1291.	-368.
19		7	27.20	63.16	24.27	12.28	1247.41	1	1170.	-437.
20		7	28.19	65.82	25.72	11.55	1297.41	1	1069.	-485.
21		7	27.03	58.15	22.96	14.27	1347.41	1	971.5	-536.
22		7	25.82	61.08	22.60	12.49	1397.41	1	874.3	-593.
23		7	27.79	61.67	24.46	13.19	1447.41	1	767.2	-652.
24		7	25.75	56.72	21.53	14.13	1497.41	1	666.4	-711.
25		7	24.43	58.45	20.82	12.78	1547.41	1	529.7	-796.
26		7	27.62	69.27	25.83	9.78	1647.41	1	323.1	-899.
27		7	21.57	67.98	20.00	8.09	1747.41	1	123.1	-977.
28		7	14.40	83.28	14.30	1.69	1847.41	1	-94.6	-.104E+04
29		7	15.45	113.84	14.13	-6.25	2067.41	1	-339.	-993.
30		7	12.10	133.78	8.74	-8.37	2247.41	1	-522.	-858.
31		7	11.00	143.27	6.58	-8.81	2447.41	1	-640.	-727.
32		7	11.28	146.86	6.16	-9.44	2647.41	1	-762.	-566.
33		7	17.88	146.47	9.88	-14.91	2897.41	1	-932.	-305.
34		7	24.01	149.84	12.06	-20.76	3147.41	1	-.128E+04	300.4
35		7	30.75	149.57	15.58	-26.51	3647.41	1	-.189E+04	1294.
36		7	34.46	149.91	17.28	-29.82	4147.41	1	-.251E+04	2365.
37		7	24.30	161.25	7.81	-23.01	4647.41	1	-.322E+04	4057.
38		7	25.20	154.96	10.67	-22.83	5647.41	1	-.395E+04	5742.
39		7	23.21	149.60	11.74	-20.01	6647.41	1	-.490E+04	7668.
40		7	21.85	158.13	8.14	-20.28	7647.41	1	-.585E+04	9606.
41		4	21.58	122.36	18.22	-11.55	9147.41	1	-.125E+05	2637.
42		3	30.60	123.12	25.63	-16.72	10647.41	1	-.130E+05	1533.
43		3	38.80	135.75	27.08	-27.79	12147.41	1	-.148E+05	3096.
44		3	37.92	142.16	23.26	-29.94	13647.41	1	-.167E+05	5363.
45		3	40.45	145.04	23.18	-33.16	15147.41	1	-.184E+05	7634.
46		3	50.38	154.46	21.72	-45.46	16647.41	1	-.204E+05	.1109E+05
47		3	50.79	171.27	7.71	-50.20	18647.41	1	-.220E+05	.1623E+05
48		3	62.76	178.85	1.26	-62.75	20647.41	1	-.225E+05	.2340E+05
49		3	78.23	189.82	-13.34	-77.09	23147.41	1	-.217E+05	.3395E+05
50		3	96.09	185.89	-9.86	-95.58	25647.41	1	-.200E+05	.4481E+05
51		3	110.59	185.97	-11.49	-109.99	28147.41	1	-.190E+05	.5549E+05

52	3	152.74	185.47	-14.57	-152.04	30647.41	1	-.175E+05	.6916E+05
53	3	122.39	196.17	-34.06	-117.54	33147.41	1	-.147E+05	.6789E+05
54	3	65.84	203.64	-26.40	-60.32	35647.41	1	-.988E+04	.9927E+05
55	3	64.84	200.60	-22.81	-60.69	38147.41	1	-.603E+04	.1090E+06
56	3	65.11	207.61	-30.18	-57.69	40647.41	1	-26.2	.1226E+06
57	3	71.86	221.20	-47.33	-54.07	45647.41	1	.1199E+05	.1398E+06
58	2	74.49	234.69	-60.79	-43.06	50647.41	1	.4284E+05	.1940E+06
59	2	80.86	236.69	-67.58	-44.40	55647.41	1	.6046E+05	.2062E+06
60	2	93.93	251.32	-88.98	-30.09	60647.41	1	.8430E+05	.2180E+06
61	2	92.62	256.98	-90.24	-20.86	65647.41	1	.1116E+06	.2250E+06
62	2	93.79	256.87	-91.34	-21.30	70647.41	1	.1409E+06	.2311E+06
63	2	102.48	264.58	-102.02	-9.67	75647.41	1	.1762E+06	.2385E+06
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67 *	0	0.00	0.00	0.00	0.00	110647.41	0	.0000	.0000
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NUMBER OF MODELS 2

21:13:53

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VELOCITY 3.7 10.2 13.1 13.4 15.4 17.9

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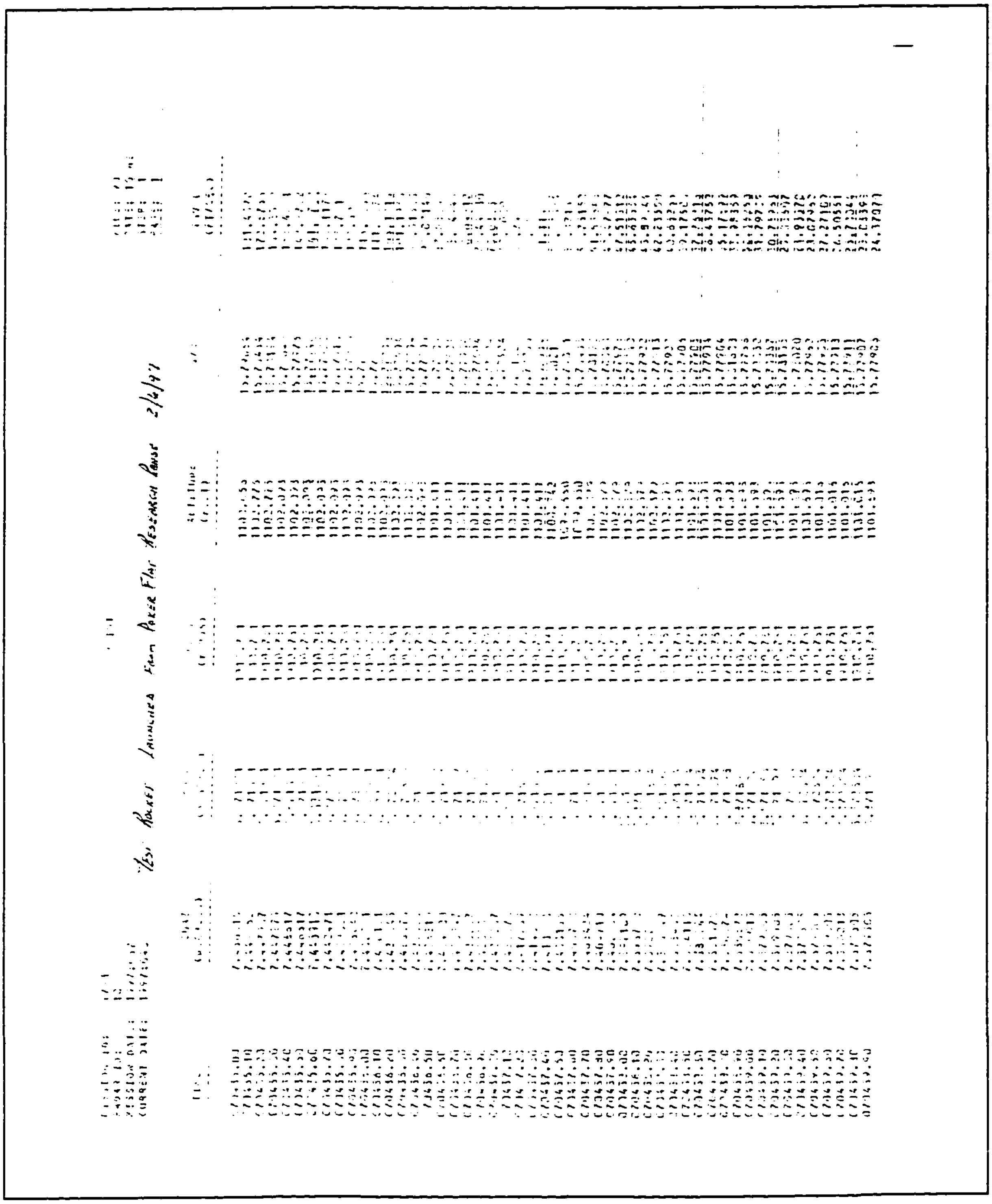
			3.1	82.66	183.05	354.9	81.56	206.30
T40011	154.6	16.76	3.0	83.00	186.37	357.2	80.90	224.29
			5.1	83.04	185.57	358.9	80.97	223.18

A.2 Radar Data


MISSION DATE:
CURRENT DATE:
Test Rocket Launched From Poker Flat Research Range 2/4/97
ALTITUDE

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070455.10	[illegible]	[illegible]	1310.751	1413.157	[illegible]	[illegible]
070455.20	[illegible]	[illegible]	1310.751	1412.351	[illegible]	[illegible]
070455.30	[illegible]	[illegible]	1310.751	[illegible]	[illegible]	[illegible]
070455.40	[illegible]	[illegible]	1310.751	1400.319	[illegible]	71.91[illegible]
070455.50	[illegible]	[illegible]	1310.751	[illegible]	15.78367	[illegible]
070455.60	[illegible]	[illegible]	1310.751	1392.519	[illegible]	[illegible]
070455.70	[illegible]	[illegible]	1310.751	[illegible]	[illegible]	[illegible]
070455.80	[illegible]	[illegible]	1310.751	1385.330	[illegible]	[illegible]
070455.90	[illegible]	[illegible]	1310.751	[illegible]	[illegible]	[illegible]
070456.00	[illegible]	[illegible]	1310.751	1379.393	[illegible]	[illegible]
070456.10	[illegible]	[illegible]	1310.751	1377.211	[illegible]	[illegible]
070456.20	[illegible]	[illegible]	1310.751	[illegible]	[illegible]	[illegible]
070456.30	[illegible]	[illegible]	1310.751	[illegible]	[illegible]	[illegible]
070456.40	[illegible]	[illegible]	1310.751	1372.704	15.77903	[illegible]
070456.50	[illegible]	[illegible]	1310.751	[illegible]	[illegible]	[illegible]
070456.60	[illegible]	[illegible]	1310.751	[illegible]	15.77934	45.30005
070456.70	[illegible]	[illegible]	1310.751	1362.777	[illegible]	[illegible]
070456.80	[illegible]	[illegible]	1310.751	[illegible]	[illegible]	[illegible]
070456.90	[illegible]	[illegible]	1310.751	1354.337	[illegible]	[illegible]
070457.00	[illegible]	[illegible]	1310.751	[illegible]	[illegible]	[illegible]
070457.10	[illegible]	[illegible]	1310.751	[illegible]	15.78122	[illegible]
070457.20	[illegible]	[illegible]	1310.751	[illegible]	15.75030	[illegible]
070457.30	[illegible]	[illegible]	1310.751	[illegible]	[illegible]	[illegible]
070457.40	[illegible]	[illegible]	1310.751	[illegible]	15.77933	40.5121
070457.50	[illegible]	[illegible]	1310.751	[illegible]	[illegible]	[illegible]
070457.60	[illegible]	[illegible]	1310.751	1337.443	[illegible]	[illegible]
070457.70	[illegible]	[illegible]	1310.751	1334.724	[illegible]	[illegible]
070457.80	[illegible]	[illegible]	1310.751	1333.355	15.77906	[illegible]
070457.90	[illegible]	[illegible]	1310.751	[illegible]	[illegible]	[illegible]
070458.00	[illegible]	[illegible]	1310.751	[illegible]	15.77904	[illegible]
070458.10	[illegible]	[illegible]	1310.751	[illegible]	15.77904	[illegible]
070458.20	[illegible]	[illegible]	1310.751	[illegible]	[illegible]	[illegible]
070458.30	[illegible]	[illegible]	1310.751	1323.743	[illegible]	[illegible]
070458.40	[illegible]	[illegible]	1310.751	1323.748	[illegible]	[illegible]
070458.50	[illegible]	[illegible]	1310.751	[illegible]	[illegible]	[illegible]
070458.60	[illegible]	[illegible]	1310.751	1317.240	[illegible]	[illegible]
070458.70	[illegible]	[illegible]	1310.751	[illegible]	[illegible]	[illegible]
070458.80	[illegible]	[illegible]	1310.751	1312.771	15.77904	[illegible]
070458.90	[illegible]	[illegible]	1310.751	1312.771	[illegible]	[illegible]
070459.00	[illegible]	[illegible]	1310.751	1312.771	[illegible]	[illegible]
070459.10	[illegible]	[illegible]	1310.751	1312.771	[illegible]	[illegible]
070459.20	[illegible]	[illegible]	1310.751	[illegible]	[illegible]	39.70171
070459.30	[illegible]	[illegible]	1310.751	[illegible]	[illegible]	[illegible]
070459.40	[illegible]	[illegible]	1310.751	[illegible]	[illegible]	39.73117
070459.50	[illegible]	[illegible]	1310.751	[illegible]	15.77904	[illegible]
070459.60	[illegible]	[illegible]	1310.751	[illegible]	[illegible]	[illegible]
070459.70	[illegible]	[illegible]	1310.751	[illegible]	[illegible]	[illegible]
070459.80	[illegible]	[illegible]	1310.751	1355.516	[illegible]	[illegible]
070459.90	[illegible]	[illegible]	1310.751	1375.423	[illegible]	34.89[illegible]

PAGE [illegible]

TIME	[illegible]	[illegible]	[illegible] (YARDS)	ALTITUDE (FEET)	S/N	LEVEL [illegible]
070500.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070500.10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070500.20	[illegible]	[illegible]	[illegible]	[illegible]	15.76077	[illegible]
070500.30	7.292272	[illegible]	1910.761	[illegible]	[illegible]	[illegible]
070500.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070500.50	[illegible]	[illegible]	[illegible]	[illegible]	15.73352	30.42479
070500.60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	70.65727
070500.70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070500.80	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070500.90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070501.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070501.10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070501.20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070501.30	[illegible]	[illegible]	[illegible]	[illegible]	15.77911	31.20026
070501.40	[illegible]	[illegible]	[illegible]	[illegible]	15.77507	[illegible]
070501.50	[illegible]	[illegible]	[illegible]	[illegible]	15.81810	[illegible]
070501.60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070501.70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070501.80	[illegible]	[illegible]	[illegible]	[illegible]	15.73367	[illegible]
070501.90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070502.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070502.10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070502.20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070502.30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070502.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070502.50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070502.60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070502.70	[illegible]	[illegible]	[illegible]	[illegible]	15.74207	[illegible]
070502.80	[illegible]	[illegible]	[illegible]	[illegible]	15.76056	[illegible]
070502.90	[illegible]	[illegible]	[illegible]	[illegible]	15.76950	[illegible]
070503.00	7.421777	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070503.10	[illegible]	[illegible]	[illegible]	5414.434	[illegible]	[illegible]
070503.20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070503.30	[illegible]	[illegible]	[illegible]	[illegible]	15.77546	[illegible]
070503.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070503.50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070503.60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070503.70	[illegible]	[illegible]	[illegible]	[illegible]	15.77500	[illegible]
070503.80	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070503.90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070504.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070504.10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070504.20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070504.30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070504.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070504.50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070504.60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070504.70*	[illegible]	[illegible]	[illegible]	5733.135	15.77511	[illegible]
070504.80*	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070504.90*	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
C70505.00*	6.775?3?	[illegible]	2154.[illegible]	3217.957	[illegible]	70.[illegible]
C70505.10*	[illegible]	[illegible]	2175.[illegible]	5417.[illegible]	[illegible]	74?.8234
C70505.20*	6.11717	[illegible]	[illegible]	[illegible]	33.00043	79?.5[illegible]
C70505.30*	5.?4011?	[illegible]	2201.155	752.215	[illegible]	[illegible]
C70505.40*	[illegible]	[illegible]	22?7.456	[illegible]	[illegible]	315.[illegible]
C70505.50*	[illegible]	[illegible]	22?4.101	5956.344	[illegible]	[illegible]
C70505.60*	[illegible]	[illegible]	[illegible]	7057.[illegible]	[illegible]	749.0911
C70505.70*	[illegible]	[illegible]	[illegible]	7145.353	[illegible]	[illegible]
C70505.80*	[illegible]	[illegible]	[illegible]	7241.[illegible]	[illegible]	[illegible]
C70505.90*	[illegible]	[illegible]	[illegible]	7347.[illegible]	[illegible]	100?.77?
C70506.00*	[illegible]	[illegible]	2511.[illegible]	7435.551	33.47731	1015.45?
C70506.10*	5.534.[illegible]	[illegible]	2545.5?4	7527.59?	[illegible]	1074.32?
C70506.20*	[illegible]	[illegible]	2574.707	7621.[illegible]	33.77[illegible]	1050.54?
C70506.30*	[illegible]	[illegible]	2512.42	7710.[illegible]	35.37?34	10??.044
C70506.40*	[illegible]	[illegible]	2547.94?	7707.797	[illegible]	[illegible]
C70506.50*	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1012.45?
C70506.60*	6.397173	[illegible]	2711.472	7972.433	35.00733	1040.51?
C70506.70*	5.705149	[illegible]	[illegible]	8077.141	[illegible]	1040.3?7
C70506.80*	[illegible]	[illegible]	2774.41?	8155.144	[illegible]	[illegible]
C70506.90*	5.?72147	[illegible]	[illegible]	8257.617	34.41534	[illegible]
C70507.00*	[illegible]	[illegible]	[illegible]	8347.147	[illegible]	1024.5??
C70507.10*	[illegible]	[illegible]	2?75.117	8439.433	[illegible]	1022.0?2
C70507.20*	6.03?111	53.?071?	[illegible]	8522.121	34.31172	1013.79?
C70507.30*	[illegible]	[illegible]	2977.517	8607.755	34.15721	[illegible]
C70507.40*	6.?03723	[illegible]	2?70.35?	8?94.377	[illegible]	1021.130
C70507.50*	[illegible]	[illegible]	[illegible]	8782.[illegible]	[illegible]	1016.741
C70507.60*	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1013.000
C70507.70*	[illegible]	[illegible]	3051.[illegible]	[illegible]	[illegible]	[illegible]
C70507.80*	5.?35?7?	[illegible]	[illegible]	9040.441	33.31370	1005.335
C70507.90*	[illegible]	??.15711	3121.164	9123.337	[illegible]	1000.555
C70508.00*	[illegible]	[illegible]	315?.4?7	9207.[illegible]	[illegible]	[illegible]
C70508.10*	5.3?31?9	54.112??	[illegible]	9290.2??	33.42539	[illegible]
C70508.20*	[illegible]	[illegible]	[illegible]	9367.775	33.05219	[illegible]
C70508.30*	[illegible]	54.15?22	3230.?75	9447.397	[illegible]	[illegible]
C70508.40*	5.395?1?	54.1?41?	3270.137	9527.504	32.52423	974.[illegible]
C70508.50*	[illegible]	[illegible]	[illegible]	9604.592	31.55?61	[illegible]
C70508.60*	[illegible]	[illegible]	[illegible]	9681.797	[illegible]	[illegible]
C70508.70*	[illegible]	[illegible]	[illegible]	9762.004	31.55474	[illegible]
C70508.80*	[illegible]	[illegible]	[illegible]	[illegible]	32.30424	[illegible]
C70508.90*	[illegible]	[illegible]	3410.27?	9916.331	[illegible]	[illegible]
C70509.00*	6.923?7?	54.27?52	3431.595	9992.719	41.35756	[illegible]
C70509.10*	5.921037	[illegible]	[illegible]	[illegible]	44.74253	934.2463
C70509.20*	6.?21647	[illegible]	3495.722	10143.51	[illegible]	92?.3877
C70509.30*	6.?20324	[illegible]	3521.691	10217.31	[illegible]	922.5325
C70509.40*	[illegible]	54.34344	[illegible]	10291.40	[illegible]	915.0394
C70509.50*	[illegible]	[illegible]	3575.331	10364.42	[illegible]	[illegible]
C70509.60*	[illegible]	54.36512	[illegible]	10439.17	[illegible]	[illegible]
C70509.70*	[illegible]	[illegible]	[illegible]	10507.49	[illegible]	[illegible]
C70509.80*	[illegible]	[illegible]	[illegible]	10583.53	46.17645	[illegible]
C70509.90*	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TIME	[illegible]	[illegible]	[illegible]	ALTITUDE (FEET)	[illegible]	[illegible] (FT/SEC)
(70510.00)	[illegible]	[illegible]	[illegible]	10722.14	[illegible]	[illegible]
(70510.10)	6.[?]1[?]11	[illegible]	[illegible]	107[?]3.51	45.34[?]20	276.5377
(70510.20)	[illegible]	[illegible]	[illegible]	10[?]5[?].51	45.36904	47[?].313
(70510.30)	[illegible]	[illegible]	[illegible]	1[?][?]1.3[?]	45.11710	[illegible]
(70510.40)	[illegible]	[illegible]	[illegible]	1[?]9[?][?].[?]7	44.3012[?]	[illegible]
(70510.50)	[illegible]	55.41101	[illegible]	11[?]67.43	44.33050	[illegible]
(70510.60)	[illegible]	[illegible]	[illegible]	11135.11	[illegible]	[illegible]
(70510.70)	[illegible]	[illegible]	[illegible]	112[?]2.77	[illegible]	[illegible]
(70510.80)	[illegible]	[illegible]	[illegible]	11270.57	47.15275	[illegible]
(70510.90)	[illegible]	[illegible]	[illegible]	11[?][?]7.22	[illegible]	832.5533
(70511.00)	[illegible]	[illegible]	[illegible]	11502.11	[illegible]	[illegible]
(70511.10)	[illegible]	[illegible]	[illegible]	11457.63	[illegible]	[illegible]
(70511.20)	[illegible]	[illegible]	[illegible]	11575.54	[illegible]	711.8201
(70511.30)	[illegible]	[illegible]	[illegible]	11630.40	[illegible]	[illegible]
(70511.40)	[illegible]	[illegible]	[illegible]	11[?][?]1.17	50.25320	[illegible]
(70511.50)	[illegible]	[illegible]	4377.75[?]	11725.73	50.77336	[illegible]
(70511.60)	[illegible]	[illegible]	4130.21[?]	11737.30	51.1[?]27[?]	[illegible]
(70511.70)	[illegible]	55.27775	4124.525	11[?]47.35	51.53120	[illegible]
(70511.80)	[illegible]	[illegible]	[illegible]	11712.07	52.47343	7[?]0.9[?]10
(70511.90)	[illegible]	[illegible]	[illegible]	11975.21	[illegible]	[illegible]
(70512.00)	[illegible]	[illegible]	[illegible]	12037.33	[illegible]	770.3252
(70512.10)	[illegible]	[illegible]	[illegible]	12099.53	52.22400	[illegible]
(70512.20)	[illegible]	[illegible]	[illegible]	12137.17	[illegible]	[illegible]
(70512.30)	[illegible]	[illegible]	[illegible]	12[?]1[?].32	52.40016	[illegible]
(70512.40)	[illegible]	[illegible]	[illegible]	12275.99	53.35075	[illegible]
(70512.50)	[illegible]	[illegible]	[illegible]	12336.43	54.3755[?]	[illegible]
(70512.60)	[illegible]	[illegible]	[illegible]	12394.37	[illegible]	[illegible]
(70512.70)	[illegible]	[illegible]	[illegible]	12455.52	[illegible]	[illegible]
(70512.80)	[illegible]	[illegible]	[illegible]	12511.25	53.3113[?]	[illegible]
(70512.90)	[illegible]	[illegible]	[illegible]	125[?][?].57	54.1[?]0[?]	[illegible]
(70513.00)	[illegible]	[illegible]	4415.545	12[?]2[?].[?]0	54.53[?][?]	[illegible]
(70513.10)	[illegible]	[illegible]	[illegible]	126[?][?].25	54.[?]311	[illegible]
(70513.20)	[illegible]	[illegible]	[illegible]	12735.8[?]	55.10043	711.1[?]
(70513.30)	[illegible]	[illegible]	[illegible]	12793.35	54.77461	[illegible]
(70513.40)	[illegible]	[illegible]	4520.117	123[?][?].40	54.53763	701.3397
(70513.50)	[illegible]	[illegible]	[illegible]	12[?][?]1.06	54.34505	[?]7.2908
(70513.60)	[illegible]	[illegible]	[illegible]	12[?]57.7[?]	54.47101	[illegible]
(70513.70)	[illegible]	54.15[?]24	[illegible]	1[?]01[?].21	54.45990	[?]3.17[?]
(70513.80)	[illegible]	[illegible]	[illegible]	13054.[?]	54.71352	[illegible]
(70513.90)	[illegible]	[illegible]	[illegible]	13119.70	54.50713	[illegible]
(70514.00)	6.[?]41220	[illegible]	[illegible]	13172.14	[illegible]	[illegible]
(70514.10)	[illegible]	[illegible]	[illegible]	13224.3[?]	54.30343	57[?].4729
(70514.20)	[illegible]	[illegible]	4554.173	13276.52	55.47451	566.1473
(70514.30)	[illegible]	[illegible]	[illegible]	13327.77	54.31354	[illegible]
(70514.40)	[illegible]	[illegible]	[illegible]	13377.20	54.55535	557.5345
(70514.50)	[illegible]	[illegible]	4732.770	13429.54	54.91502	[illegible]
(70514.60)	[illegible]	[illegible]	[illegible]	13479.06	55.01525	[illegible]
(70514.70)	[illegible]	[illegible]	[illegible]	13530.23	54.05774	[illegible]
(70514.80)	[illegible]	[illegible]	[illegible]	13577.75	54.4772[?]	541.1597
(70514.90)	[illegible]	[illegible]	[illegible]	13[?]20.20	54.27314	[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible] (FT.1)	[illegible]	[illegible]
070515.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070515.10	[illegible]	[illegible]	[illegible]	13726.45	54.13405	[illegible]
070515.20	[illegible]	[illegible]	[illegible]	13775.29	[illegible]	[illegible]
070515.30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070515.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070515.50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070515.60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070515.70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070515.80	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070515.90	[illegible]	[illegible]	[illegible]	[illegible]	53.30315	[illegible]
070516.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070516.10	[illegible]	[illegible]	[illegible]	14142.27	[illegible]	[illegible]
070516.20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070516.30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070516.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070516.50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070516.60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070516.70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070516.80	[illegible]	[illegible]	[illegible]	14441.36	[illegible]	[illegible]
070516.90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070517.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070517.10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070517.20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070517.30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070517.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070517.50	[illegible]	[illegible]	[illegible]	14722.35	[illegible]	[illegible]
070517.60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070517.70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070517.80	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070517.90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070518.00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070518.10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070518.20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070518.30	[illegible]	[illegible]	[illegible]	15025.36	53.57439	[illegible]
070518.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070518.50	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070518.60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070518.70	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070518.80	[illegible]	[illegible]	[illegible]	15201.72	[illegible]	[illegible]
070518.90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070519.00	[illegible]	[illegible]	[illegible]	15259.74	[illegible]	[illegible]
070519.10	[illegible]	[illegible]	[illegible]	15304.11	[illegible]	[illegible]
070519.20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070519.30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070519.40	[illegible]	[illegible]	[illegible]	15400.31	[illegible]	[illegible]
070519.50	[illegible]	[illegible]	[illegible]	15433.42	[illegible]	[illegible]
070519.60	[illegible]	[illegible]	5344.551	15455.35	[illegible]	[illegible]
070519.70	[illegible]	[illegible]	[illegible]	15475.23	[illegible]	[illegible]
070519.80	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070519.90	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TIME	[illegible] (DEGREES)	[illegible] (DEGREES)	[illegible] (YARDS)	ALTITUDE (FEET)	[illegible]	[illegible] (FT/SEC)
070520.00	[illegible]	[illegible]	5597.492	15615.75	54.43439	451.2171
070520.10	[illegible]	[illegible].34541	5623.561	15645.75	55.77427	453.3123
070520.20	6.372031	[illegible]	5571.301	15676.13	55.39405	452.3511
070520.30	6.356543	52.35375	5641.356	15704.77	53.31723	449.4192
070520.40	[illegible]	52.22915	5590.270	15732.44	53.56030	446.51[illegible]
070520.50	6.352[illegible]51	52.15127	5573.437	15759.45	51.70853	447.611[illegible]
070520.60	[illegible]	51.95521	5655.173	15786.42	54.14037	443.7341
070520.70	6.35[illegible]	[illegible]	5591.562	15813.02	54.07243	437.79[illegible]
070520.80	5.365555	52.05177	5712.337	15840.01	54.77921	434.3759
070520.90	5.365150	52.02751	5722.215	15866.61	55.425[illegible]	431.7798
070521.00	5.370244	51.99531	5734.445	15893.53	55.43740	429.1255
070521.10	[illegible]	51.94447	5749.177	15919.52	55.32349	426.3071
070521.20	6.3[illegible]5215	[illegible]	5750.[illegible]	15947.19	55.07155	423.5[illegible]
070521.30	5.361742	51.[illegible]	5771.113	15973.11	54.75232	420.75[illegible]
070521.40	5.350744	51.82[illegible]	5781.31[illegible]	15995.50	54.56733	415.0265
070521.50	[illegible]	51.74[illegible]	5795.[illegible]	16023.98	54.54145	413.3377
070521.60	6.351257	51.73[illegible]	5827.734	16047.13	55.25255	412.5133
070521.70	[illegible]	51.[illegible]	5816.477	16070.53	54.37712	40[illegible]
070521.80	[illegible]	51.2512[illegible]	5839.215	16093.51	55.13533	407.2[illegible]74
070521.90	[illegible]	51.[illegible]13	5853.397	16117.35	55.45149	404.6517
070522.00	[illegible]	51.55255	5151.575	16141.05	55.2144[illegible]	402.04[illegible]
070522.10	[illegible]	51.51251	5862.413	16164.25	55.75015	399.45[illegible]
070522.20	5.341927	51.45254	5871.207	16184.73	55.46951	397.7903
070522.30	5.344533	51.42056	5882.433	16205.21	55.73700	[illegible]4.1201
070522.40	[illegible]	[illegible]	5892.695	16225.35	54.92530	[illegible]1.753[illegible]
070522.50	[illegible]	[illegible]	5902.945	16246.35	54.73973	[illegible]
070522.60	[illegible]	51.[illegible]	5914.351	16257.34	[illegible]	[illegible]6.52[illegible]
070522.70	[illegible]	[illegible]	5926.37[illegible]	16287.32	[illegible]	[illegible]4.37[illegible]
070522.80	[illegible]	51.30215	5935.172	16307.82	55.33795	381.5335
070522.90	[illegible]	[illegible]	5945.402	16327.04	55.17573	379.0605
070523.00	[illegible]	[illegible]	5955.555	16347.52	55.14612	376.5706
070523.10	5.324710	51.05572	5957.191	16365.24	55.24194	374.1236
070523.20	5.321[illegible]	51.06[illegible]	5976.630	16385.77	54.91945	371.7124
070523.30	[illegible]	52.9404[illegible]	5976.445	16408.11	53.96923	369.3741
070523.40	5.317027	[illegible].91443	5994.743	16425.26	54.34421	366.9512
070523.50	[illegible]	[illegible]	6003.557	16443.02	55.[illegible]3906	364.5541
070523.60	6.332345	[illegible]	6012.312	16459.72	53.35700	352.3452
070523.70	[illegible]	[illegible].76[illegible]	6022.574	16477.43	53.75974	360.0257
070523.80	6.31[illegible]	52.71[illegible]	6031.[illegible]55	16491.46	54.32551	357.7117
070523.90	6.81[illegible]	[illegible]312	6042.545	16509.54	54.33753	355.4357
070524.00	5.812471	53.31591	6050.410	16522.52	54.60342	353.1152
070524.10	5.307[illegible]	[illegible]	6061.149	16540.26	54.60019	350.[illegible]
070524.20	5.[illegible]7171	50.51[illegible]	6068.955	16556.29	54.45735	361.5438
070524.30	5.7[illegible]475	[illegible].4517	6079.[illegible]	16571.34	51.46823	346.4533
070524.40	6.774403	50.41[illegible]	6084.[illegible]	16584.55	52.73610	344.2917
070524.50	6.77[illegible]0	53.31039	6093.[illegible]	16598.51	53.13500	342.1399
070524.60	5.309955	51.31221	6100.705	16612.97	51.64353	340.3042
070524.70	5.311255	51.25522	6112.004	16626.75	51.05255	337.3135
070524.80	6.307734	[illegible]	6117.325	16637.52	51.42023	335.7795
070524.90	[illegible]	53.14532	6125.117	16651.50	51.93443	333.6763

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TIME	CUAZ (DEGREES)	[illegible] ([illegible])	[illegible] (YARDS)	ALTITUDE (FEET)	S/N	TGVEL (FT/SEC)
070525.00	0.757[illegible]	50.09796	5135.33[illegible]	16662.07	52.0[illegible]	331.6301
070525.10	0.7375[illegible]	50.04[illegible]	5144.156	16573.37	51.6713[illegible]	329.5[illegible]
070525.20	0.770[illegible]	5[illegible].5[illegible]76	5151.959	16635.63	51.50463	327.5339
070525.30	0.771535	5[illegible]	5150.753	16599.92	51.72155	325.6[illegible]
070525.40	0.775514	5[illegible]	5153.[illegible]	16710.50	50.61620	323.7[illegible]7
070525.50	0.775[illegible]	5[illegible]	5175.465	16722.[illegible]	4[illegible].[illegible]522	321.[illegible]
070525.60	0.7[illegible]	5[illegible]	5182.7[illegible]	16733.39	45.62527	319.9573
070525.70	0.773773	[illegible].72[illegible]24	5190.54[illegible]	16744.55	47.33159	31[illegible]
070525.80	0.745690	5[illegible]	5197.557	16755.23	45.77595	31[illegible]
070525.90	0.775[illegible]	55.57[illegible]	5204.707	167[illegible]	47.52526	314.5563
070526.00	0.752459	5[illegible].54739	5212.515	16775.31	4[illegible].73721	312.5814
070526.10	0.753230	5[illegible]	5219.144	167[illegible]3.17	4[illegible].0146[illegible]	310.[illegible]04
070526.20	[illegible].755225	5[illegible].41693	5224.727	16791.02	47.17553	30[illegible]
070526.30	0.757773	5[illegible]	5232.047	16797.11	4[illegible].22275	307.6447
070526.40	0.750318	55.3[illegible]	5242.[illegible]	16[illegible]	45.37067	30[illegible]
070526.50	0.754517	5[illegible]	525[illegible]	16815.14	4[illegible]	304.[illegible]
070526.60	0.755214	5[illegible]	525[illegible].07	16825.04	45.35170	302.[illegible]
070526.70	0.7[illegible]	5[illegible].1[illegible]331	525[illegible]	16[illegible]27.11	44.5[illegible]146	301.4111
070526.80	0.76771[illegible]	5[illegible]	52[illegible].7[illegible]	16[illegible]34.96	45.34622	[illegible]
070526.90	0.757331	5[illegible]	527[illegible]	16[illegible]41.75	4[illegible].71014	29[illegible].4692
070527.00	0.752046	[illegible]5577	527[illegible]	16[illegible]46.39	45.70[illegible]	297.0[illegible]
070527.10	0.757037	56.[illegible]	52[illegible]	16[illegible]53.65	47.6[illegible]72	29[illegible].9[illegible]
070527.20	0.75[illegible]597	5[illegible].13525	5290.545	16[illegible]57.75	47.52749	29[illegible].2559
070527.30	0.750[illegible]	5[illegible].77411	5295.[illegible]	16[illegible]62.93	47.1[illegible]4	29[illegible]
070527.40	0.757735	5[illegible].70[illegible]21	5302.[illegible]	16[illegible]65.95	47.15[illegible]4	291.[illegible]
070527.50	0.752[illegible]	5[illegible]	5311.1[illegible]	16571.02	47.95171	290.4021
070527.60	0.75[illegible]	5[illegible].5[illegible]1	5315.[illegible]	16[illegible]74.41	4[illegible].64453	2[illegible].17[illegible]
070527.70	0.75[illegible]	5[illegible].521[illegible]	5321.[illegible]	16[illegible]5.27	4[illegible].99051	2[illegible].0151
070527.80	0.744[illegible]	5[illegible].40[illegible]	5325.[illegible]1	16[illegible].52	4[illegible].71970	2[illegible].1774
070527.90	0.7[illegible]	5[illegible]	5332.611	16[illegible]90.69	50.04[illegible]	2[illegible]
070528.00	0.757[illegible]	5[illegible]	5335.495	16[illegible]94.75	45.45[illegible]1	2[illegible]4.722[illegible]
070528.10	0.7[illegible]	5[illegible].2[illegible]41	5342.591	16[illegible]75.11	4[illegible].14784	2[illegible]3.5907
070528.20	0.717342	5[illegible].21[illegible]	534[illegible].79[illegible]	16[illegible]00.13	4[illegible].1[illegible]	2[illegible]
070528.30	0.757[illegible]	5[illegible].14[illegible]5	5352.16[illegible]	16901.53	44.199[illegible]	2[illegible]1.7[illegible]
070528.40	0.744[illegible]	57.077[illegible]1	5355.515	16902.20	45.74214	2[illegible].7527
070528.50	0.71[illegible]	5[illegible].013[illegible]	53[illegible].55[illegible]	16[illegible]05.55	4[illegible].07913	27[illegible]
070528.60	0.713543	57.74[illegible]	5359.354	16[illegible]4.21	50.[illegible]750	27[illegible]
070528.70	0.715327	5[illegible].7[illegible]	5375.117	169[illegible]4.39	50.31570	275.1215
070528.80	0.712456	57.[illegible]	537[illegible].551	16[illegible]26.24	50.2310[illegible]	277.3423
070528.90	0.71[illegible]	[illegible].77734	53[illegible]1.45[illegible]	16[illegible]	49.[illegible]121	27[illegible]111
070529.00	0.721[illegible]	57.67[illegible]	5397.[illegible]	16[illegible]33.79	4[illegible].17172	27[illegible]
070529.10	[illegible].72[illegible]431	57.5[illegible]	53[illegible]1.71[illegible]	16905.14	46.95754	27[illegible]
070529.20	0.725122	57.5[illegible]	[illegible]395.137	16902.32	4[illegible].76793	274.5511
070529.30	0.731274	57.4[illegible]	5400.[illegible]	168[illegible]9.[illegible]	45.[illegible]	274.0[illegible]
070529.40	0.731177	57.4[illegible]	54[illegible]	16[illegible]97.54	46.19350	27[illegible].537[illegible]
070529.50	0.737[illegible]	57.35[illegible]	54[illegible].11[illegible]	16[illegible]95.48	45.95954	27[illegible]
070529.60	0.727[illegible]	57.[illegible]	5412.[illegible]	16[illegible]94.13	47.35713	27[illegible]
070529.70	0.71[illegible]	5[illegible].1[illegible]	541[illegible]	16[illegible]71.00	4[illegible].22481	27[illegible]
070529.80	0.737[illegible]	57.12[illegible]	5423.523	16[illegible]5.23	4[illegible].52250	271.0550
070529.90	0.7[illegible]	57.0[illegible]	[illegible]423.457	16[illegible].79	4[illegible]	271.25[illegible]

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TIME	COAZ (DEGREES)	COEL (DEGREES)	CORG (YARDS)	ALTITUDE (FEET)	S/N	TSVEL (FT/SEC)
070530.00*	6.762965	[illegible]	6425.405	16361.74	[illegible]	[illegible]
070530.10*	6.594206	[illegible]	6431.273	15975.91	48.42059	270.5210
070530.20*	6.544451	[illegible]	6432.243	16171.14	49.2363	270.3791
070530.30*	6.674773	[illegible]	6438.594	16565.30	47.20059	270.4212
070530.40*	6.687676	55.67511	6442.008	[illegible]	47.30219	[illegible]
070530.50*	6.735551	[illegible]	6446.191	16653.63	45.10293	269.5555
070530.60*	6.721920	[illegible]	6451.295	16650.51	45.10715	[illegible]
070530.70*	6.714934	[illegible]	6451.265	16745.36	[illegible]	[illegible]
070530.80*	6.701626	[illegible]	6454.737	16937.67	50.51135	[illegible]
070530.90*	[illegible]	[illegible]	6456.135	[illegible]	51.36317	[illegible]
070531.00*	[illegible]	[illegible]	6462.027	16826.19	51.94573	[illegible]
070531.10*	6.637161	[illegible]	6463.496	16817.64	51.34523	[illegible]
070531.20*	[illegible]	[illegible]	6466.495	16811.60	49.97019	[illegible]
070531.30*	[illegible]	[illegible]	6467.687	16803.25	49.17256	269.7183
070531.40*	[illegible]	[illegible]	6473.259	16794.69	50.40317	269.2750
070531.50*	[illegible]	[illegible]	6476.152	16786.13	51.55182	[illegible]
070531.60*	6.672256	[illegible]	6479.117	16770.50	52.05542	[illegible]
070531.70*	[illegible]	[illegible]	6479.605	16771.74	52.74555	270.5425
070531.80*	[illegible]	[illegible]	[illegible]	16761.43	53.35496	270.6455
070531.90*	[illegible]	[illegible]	[illegible]	16753.93	53.99596	271.2012
070532.00*	[illegible]	55.47144	[illegible]	16741.61	[illegible]	271.5547
070532.10*	[illegible]	[illegible]	[illegible]	16735.05	54.23003	271.9614
070532.20*	6.674521	[illegible]	6496.140	16724.09	[illegible]	[illegible]
070532.30*	[illegible]	[illegible]	[illegible]	16714.47	54.05472	[illegible]
070532.40*	[illegible]	[illegible]	6493.277	16703.20	52.51053	[illegible]
070532.50*	[illegible]	[illegible]	[illegible]	[illegible]	52.32047	[illegible]
070532.60*	[illegible]	[illegible]	[illegible]	16579.57	53.37167	[illegible]
070532.70*	6.621729	[illegible]	6498.659	16667.52	54.13248	[illegible]
070532.80*	6.651110	[illegible]	[illegible]	16655.26	54.25260	[illegible]
070532.90*	[illegible]	[illegible]	6502.044	16644.00	54.30175	275.2395
070533.00*	6.646654	[illegible]	[illegible]	16630.96	56.32623	276.9650
070533.10*	[illegible]	[illegible]	6507.425	16615.91	63.08175	[illegible]
070533.20*	6.627657	[illegible]	6507.441	16603.96	[illegible]	[illegible]
070533.30*	[illegible]	[illegible]	[illegible]	16590.74	[illegible]	[illegible]
070533.40*	6.621250	[illegible]	6512.409	[illegible]	[illegible]	276.3007
070533.50*	[illegible]	[illegible]	[illegible]	16563.92	64.42253	[illegible]
070533.60*	[illegible]	[illegible]	[illegible]	[illegible]	62.1410	261.7424
070533.70*	6.635115	[illegible]	6513.798	16533.11	60.44424	[illegible]
070533.80*	[illegible]	[illegible]	6513.301	16517.37	[illegible]	[illegible]
070533.90*	[illegible]	[illegible]	6513.759	16502.31	61.39213	[illegible]
070534.00*	6.644104	[illegible]	6513.301	16483.54	60.9949	[illegible]
070534.10*	[illegible]	[illegible]	6514.752	16468.10	55.42564	[illegible]
070534.20*	[illegible]	[illegible]	6514.762	16450.37	[illegible]	[illegible]
070534.30*	[illegible]	[illegible]	6516.227	16431.56	[illegible]	[illegible]
070534.40*	[illegible]	[illegible]	[illegible]	16416.12	[illegible]	[illegible]
070534.50*	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
070534.60*	6.627053	[illegible]	6517.207	16379.87	55.17173	[illegible]
070534.70*	[illegible]	[illegible]	[illegible]	16360.34	[illegible]	[illegible]
070534.80*	[illegible]	[illegible]	6517.691	[illegible]	[illegible]	[illegible]
070534.90*	6.610381	[illegible]	6517.203	16325.42	55.17591	[illegible]

TIME	[illegible] (DEGREES)	[illegible] (DEGREES)	[illegible] (YARDS)	ALTITUDE (FEET)	[illegible]	[illegible] (FT/SEC)
070535.00	[illegible]	[illegible]	5517.293	16332.23	55.34741	297.37[illegible]
070535.10	[illegible]	[illegible]	5517.671	16234.45	55.39619	[illegible]
070535.20	6.620[illegible]	52.3[illegible]	5517.249	16232.21	55.59[illegible]	300.[illegible]
070535.30	6.622771	52.[illegible]	5514.717	16243.74	55.16522	301.4277
070535.40	6.624739	52.[illegible]17	5515.330	16221.49	54.55773	30[illegible].1393
070535.50	6.622141	[illegible]	5517.[illegible]	16200.31	54.65440	[illegible]
070535.60	6.621[illegible]	[illegible]	5515.749	16178.06	54.77254	303.7[illegible]
070535.70	6.621243	51.1[illegible]175	5515.227	16159.60	54.53373	[illegible].1799
070535.80	6.617715	[illegible]	5515.735	16137.35	55.33914	[illegible]
070535.90	6.61[illegible]	[illegible]155	5515.719	16115.17	55.22017	[illegible]
070536.00	6.617323	[illegible]	5515.732	16075.92	55.56337	311.7[illegible]
070536.10	6.611260	51.7[illegible]	5512.324	16070.02	55.[illegible]7125	313.2710
070536.20	6.60[illegible]357	51.67[illegible]	5512.324	16047.77	5[illegible].27115	314.[illegible]
070536.30	6.61[illegible]	51.[illegible]	5513.324	16022.40	54.7[illegible]	315.[illegible]
070536.40	6.59071[illegible]	[illegible]	[illegible]12.320	16001.62	54.69142	31[illegible].0474
070536.50	6.60[illegible]	[illegible]	5510.337	15979.52	54.[illegible]	[illegible]
070536.60	6.601 [illegible]6	51.2[illegible]152	5509.331	15953.72	54.55502	321.31[illegible]
070536.70	6.5[illegible]	[illegible]1.17[illegible]0	[illegible]	15931.73	[illegible]	322.[illegible]
070536.80	6.5[illegible]	51.077[illegible]	[illegible]	15907.35	54.90331	324.[illegible]
070536.90	6.5[illegible]1317	[illegible]	5507.4[illegible]	15[illegible]2.20	54.60222	32[illegible]
070537.00	6.5[illegible]	50.[illegible]	5505.030	15857.23	54.[illegible]	3[illegible].0343
070537.10	[illegible]570452	[illegible]	5504.512	15832.27	[illegible]	32[illegible]
070537.20	6.55437[illegible]	50.55030	5501.532	15804.55	[illegible]	331.3457
070537.30	6.5[illegible]	50.55736	5500.505	15773.93	53.43145	33[illegible].297[illegible]
070537.40	[illegible]	[illegible]	5502.117	15751.24	53.74[illegible]	335.06[illegible]
070537.50	6.5[illegible]	[illegible]	5497.134	15725.27	54.2[illegible]104	33[illegible].3525
070537.60	6.55[illegible]	[illegible]	5496.49[illegible]	15697.91	54.2[illegible]	33[illegible]
070537.70	6.57[illegible]	[illegible]	[illegible]	15672.[illegible]	[illegible]	3[illegible]
070537.80	6.571[illegible]	[illegible]	5490.341	15644.57	53.07602	34[illegible].2850
070537.90	6.557737	[illegible]	5492.375	15615.31	55.13231	344.12[illegible]
070538.00	6.56[illegible]	[illegible]	5473.[illegible]	15585.79	53.[illegible]	34[illegible]
070538.10	6.56[illegible]	[illegible]	[illegible]	15553.11	52.17091	347.66[illegible]
070538.20	6.555[illegible]	[illegible]544	[illegible]	15523.67	52.[illegible]602	349.7[illegible]
070538.30	6.572135	[illegible]672[illegible]4	[illegible]1.553	15500.93	53.[illegible]703	351.[illegible]
070538.40	6.5[illegible]317	[illegible]	[illegible]1.071	15467.19	5[illegible]	35[illegible]
070538.50	6.551[illegible]	[illegible]	[illegible]	15442.21	53.56455	355.5115
070538.60	6.555[illegible]	[illegible]	5477.145	15413.77	54.67523	357.450[illegible]
070538.70	6.557[illegible]	[illegible]	5475.1[illegible]	15382.35	54.93240	359.379[illegible]
070538.80	6.5[illegible]	[illegible]	5473.25	15351.22	53.72755	361.55[illegible]
070538.90	6.5[illegible]	[illegible]	5459.235	15319.12	52.90[illegible]	[illegible]
070539.00	6.5[illegible]	[illegible]67535	5455.934	15288.71	51.4904[illegible]	365.[illegible]458
070539.10	6.55[illegible]	[illegible]533	5455.44[illegible]	15257.62	52.11771	367.2010
070539.20	6.552774	43.4443[illegible]	5461.475	15226.15	53.35100	369.1790
070539.30	6.547145	[illegible]33317	5459.102	15195.06	53.42154	371.1595
070539.40	6.528181	[illegible]21027	5457.147	15161.25	55.19437	373.1345
070539.50	6.53[illegible]	[illegible]	5453.73[illegible]	15129.10	53.[illegible]	375.1123
070539.60	6.533172	[illegible]7745	5450.312	15095.93	53.37954	377.0967
070539.70	6.5[illegible]	[illegible]	5449.[illegible]	15063.32	51.91217	379.0915
070539.80	6.5[illegible]	[illegible]7[illegible]502	5447.557	15030.31	50.14575	381.09[illegible]
070539.90	6.554[illegible]	[illegible]	5445.43[illegible]	14997.35	51.694[illegible]	[illegible].1057

Time	[illegible]	[illegible]	[illegible]	ALTITUDE (FEET)	[illegible]	Level [illegible]
070540.00	6.535530	47.41990	5442.315	14754.05	52.25657	385.1125
070540.10	6.531333	47.35550	5439.0[illegible]3	1492[illegible].13	53.91004	387.1353
070540.20	6.531730	47.24344	5434.537	14394.30	52.99219	389.1479
070540.30	6.532530	47.12452	5434.179	14460.30	53.27322	391.1241
070540.40	6.540671	45.79537	5430.731	14426.30	52.99005	393.2203
070540.50	6.522755	[illegible]	5424.32[illegible]	14771.43	52.55342	395.2251
070540.60	6.528733	45.72772	5423.477	14753.55	50.61432	397.5222
070540.70	6.522775	46.55123	5422.477	14713.96	52.30937	399.394
070540.80	6.520453	45.51213	5419.052	14531.36	53.50133	401.4770
070540.90	6.520352	46.35793	5414.553	15549.62	54.43220	403.3557
070541.00	6.513374	[illegible]	5407.333	14403.96	54.47357	405.3572
070541.10	6.511215	[illegible]	5405.352	14372.37	52.7[illegible]	407.5[illegible]
070541.20	6.507322	45.[illegible]1192	5403.557	14537.50	51.3[illegible]	409.7410
070541.30	6.50[illegible]	[illegible]	5401.963	14499.93	51.[illegible]1515	411.8031
070541.40	6.499307	45.74445	5399.32[illegible]	14435.33	52.31153	413.7347
070541.50	6.497215	45.51361	5395.133	14423.73	53.89033	415.1233
070541.60	6.499775	45.4[illegible]77	[illegible]2.635	14390.51	54.05021	417.3162
070541.70	6.504301	45.32134	5393.253	14332.91	55.45535	419.5267
070541.80	6.501474	[illegible]	5384.395	14315.32	51.36939	421.3213
070541.90	6.505653	45.[illegible]	5382.930	14277.73	51.05713	423.7511
070542.00	6.500331	44.76160	5375.117	14237.41	52.55550	425.[illegible]
070542.10	6.477353	44.[illegible]	5371.699	14199.42	53.47133	427.3110
070542.20	6.476617	44.[illegible]	5371.355	14155.51	54.35041	429.7751
070542.30	6.479243	44.55[illegible]	[illegible]	14121.31	54.1673	431.72[illegible]
070542.40	6.433733	44.33177	5361.934	140[illegible]0.92	53.66137	433.[illegible]
070542.50	6.47[illegible]	[illegible]	5359.005	14040.01	51.21152	435.5331
070542.60	6.433271	44.14[illegible]47	5355.535	14000.23	52.01527	437.511[illegible]
070542.70	[illegible]	44.[illegible]	5351.[illegible]	13959.30	53.02523	439.[illegible]
070542.80	6.471313	[illegible]	5349.2[illegible]	13914.93	54.247[illegible]3	441.5735
070542.90	6.430777	43.73[illegible]	5342.391	13877.51	54.37057	443.3431
070543.00	6.472434	43.59175	5334.355	13834.57	52.3053	445.5107
070543.10	6.431[illegible]	4[illegible].45[illegible]7	5334.051	13793.5[illegible]	50.77524	447.4[illegible]
070543.20	6.432271	43.39[illegible]	5334.599	13753.27	51.33725	449.4592
070543.30	6.453261	43.17355	5323.733	13709.55	52.45937	451.433[illegible]
070543.40	6.451479	43.04175	5324.124	13551.17	53.77453	453.3[illegible]
070543.50	6.4[illegible]	42.[illegible]911	5320.711	13524.46	51.03065	455.[illegible]
070543.60	6.4[illegible]1333	4[illegible].7320[illegible]	5317.4[illegible]	13534.15	53.39173	457.3[illegible]
070543.70	6.4[illegible]7[illegible]7	[illegible]	5309.179	13541.11	51.92714	459.2[illegible]
070543.80	6.431[illegible]	42.47531	5307.730	13477.02	52.25845	461.1555
070543.90	6.43167[illegible]	42.[illegible]551	5304.312	13453.33	53.15363	463.3545
070544.00	6.453371	42.1[illegible]	5299.434	13412.99	53.39550	234.5536
070544.10	6.452[illegible]	42.03[illegible]	5296.933	13319.96	54.77590	465.1533
070544.20	6.427434	41.91153	5292.394	13325.13	54.13132	467.7319
070544.30	6.423937	41.75137	5289.130	13232.14	52.32673	470.5313
070544.40	6.423177	41.57135	5282.344	13235.71	52.33779	472.3572
070544.50	6.430353	41.74[illegible]51	5277.461	13192.51	53.34423	474.1592
070544.60	6.424377	41.29[illegible]7	5274.041	13143.13	52.75531	476.0310
070544.70	6.430310	41.1[illegible]	5273.133	13102.15	53.72311	477.3[illegible]84
070544.80	6.431065	41.07[illegible]	5256.337	13054.65	53.46023	479.7363
070544.90	6.431510	41.[illegible]413[illegible]	5251.14[illegible]	13003.90	53.34254	481.3330

TIME	[illegible] (DEGREES)	[illegible] (DEGREES)	[illegible] (YARDS)	ALTITUDE (FEET)	[illegible]	[illegible] (FT/SEC)
070545.00	0.430111	[illegible]	[illegible]	12961.43	52.71043	[illegible]
070545.10	0.417252	40.54727	5252.117	12915.55	53.03125	415.3250
070545.20	0.416455	40.40240	5245.311	12863.14	53.32901	417.2057
070545.30	0.422100	40.25344	[illegible]	12822.37	54.10187	[illegible]
070545.40	0.420103	40.07352	[illegible]	12772.13	54.20125	[illegible]
070545.50	0.416537	[illegible]	[illegible]	12724.5	53.32455	[illegible]
070545.60	0.422744	[illegible]	[illegible]	12673.93	53.14037	[illegible]
070545.70	0.419750	[illegible]	[illegible]	12625.71	53.13071	495.7327
070545.80	0.411513	[illegible]	[illegible]	12581.39	53.71567	[illegible]
070545.90	0.407327	[illegible]	5215.459	12535.43	[illegible]	[illegible]
070546.00	0.392531	38.14726	5211.055	12485.23	[illegible]	[illegible]
070546.10	0.37071	[illegible]	[illegible]	12435.02	54.39424	504.5134
070546.20	0.356359	[illegible]	[illegible]	12385.06	53.07993	505.4444
070546.30	0.357074	[illegible]	[illegible]	12334.32	54.51571	[illegible]
070546.40	[illegible]	[illegible]	[illegible]	12285.32	54.73449	512.3821
070546.50	0.354151	[illegible]	5190.547	12233.51	53.41832	513.3437
070546.60	0.336132	38.17751	5187.129	12171.39	54.10175	514.2774
070546.70	0.331737	[illegible]	5183.233	12143.17	52.07301	516.2455
070546.80	0.327044	[illegible]	5175.375	12093.67	52.11126	[illegible]
070546.90	0.375376	[illegible]	5172.477	12045.45	53.35175	520.1267
070547.00	0.372423	[illegible]	[illegible]	11992.26	51.37251	522.3512
070547.10	0.371335	[illegible]	5163.571	11942.04	[illegible]	[illegible]
070547.20	0.373245	37.16515	5159.745	11891.32	54.37513	525.7321
070547.30	0.372032	37.31907	5154.415	11841.60	55.25572	527.3123
070547.40	0.332605	35.34595	5147.575	11791.55	[illegible]	529.7173
070547.50	0.353434	[illegible]	5150.739	11725.73	54.50455	531.521
070547.60	[illegible]	[illegible]	5140.731	11693.47	[illegible]	[illegible]
070547.70	[illegible]	[illegible]	5135.344	11632.57	53.62941	[illegible]
070547.80	0.345736	[illegible]	[illegible]	11579.63	54.11117	[illegible]
070547.90	0.347744	[illegible]	5127.575	11526.67	54.11223	537.2571
070548.00	0.331793	[illegible]	[illegible]	11471.06	[illegible]	541.1741
070548.10	0.334532	[illegible]	[illegible]	11417.33	54.39201	543.1143
070548.20	[illegible]	[illegible]	5112.422	11364.07	54.27040	545.3525
070548.30	0.337647	35.27773	[illegible]	11311.15	54.17461	547.3356
070548.40	0.335523	35.10257	5105.596	11253.21	54.53324	[illegible]
070548.50	0.333636	34.92641	5101.153	11200.53	54.35315	550.9925
070548.60	[illegible]	34.75573	[illegible]	11147.17	54.35157	552.9727
070548.70	[illegible]	[illegible]	[illegible]	11092.31	55.21875	554.3555
070548.80	0.330653	[illegible]	[illegible]	11035.55	55.27326	555.9455
070548.90	0.314759	[illegible]	[illegible]	10983.61	55.03577	555.3107
070549.00	0.311951	34.03374	5073.239	10925.39	54.19688	[illegible]
070549.10	[illegible]	[illegible]	5070.714	10870.55	54.79324	562.3423
070549.20	0.313353	[illegible]	[illegible]	10814.19	54.97142	[illegible]
070549.30	0.315121	33.47552	5062.129	10761.75	55.34683	[illegible]
070549.40	[illegible]	[illegible]	5055.777	10702.51	55.75973	[illegible]
070549.50	[illegible]	33.16751	[illegible]	10645.35	54.92407	[illegible]
070549.60	0.323115	32.95032	5050.353	10591.23	54.71235	[illegible]
070549.70	0.313213	[illegible]	[illegible]	10535.77	54.75281	[illegible]
070549.80	0.307107	32.56775	5042.591	10475.41	53.74827	[illegible]
070549.90	[illegible]	[illegible]	6035.762	10413.67	54.02475	[illegible]

[illegible] 1

TIME	[illegible] (0.[illegible])	[illegible] ([illegible])	[illegible] (YARDS)	ALTITUDE (FEET)	[illegible]	[illegible] (FT/SEC)
C70550.00*	6.2[illegible]	[illegible]	5031.35	10355.01	54.75534	[illegible].5112
C70550.10*	6.231735	31.9[illegible]	5025.016	10304.55	54.93542	542.5547
C70550.20*	6.2[illegible]154	31.5[illegible]	5024.134	10245.51	55.05210	534.5144
C70550.30*	6.2[illegible]411	31.56154	5015.71	10138.47	55.12606	[illegible].4421
C70550.40*	6.2[illegible]133	31.41[illegible]	5013.222	10130.49	55.00355	[illegible].3232
C70550.50*	6.30[illegible]	31.32540	5011.332	10070.37	55.06257	570.2[illegible]
C70550.60*	6.27[illegible]	31.62[illegible]	5007.431	10011.77	55.12616	577.2134
C70550.70*	6.270057	[illegible].32[illegible]01	5000.535	9952.547	55.17459	594.1377
C70550.80*	6.291154	[illegible]	5000.113	9945.161	55.00705	594.0574
C70550.90*	6.2269[illegible]1	30.4[illegible]1	5973.377	9834.723	55.50277	527.9732
C70551.00*	6.2[illegible]305	30.24277	5963.775	9774.593	55.63103	599.1997
C70551.10*	6.27[illegible]553	30.347[illegible]4	5957.305	9712.223	55.10232	601.3145
C70551.20*	6.276334	[illegible]	5934.200	9652.394	55.97716	603.7232
C70551.30*	6.255375	29.55474	5977.134	9577.719	55.34221	635.6340
C70551.40*	6.257756	29.437[illegible]8	5975.251	9515.555	56.27445	537.5075
C70551.50*	6.253975	29.245[illegible]2	5925.755	9475.410	55.37023	[illegible].2322
C70551.60*	6.257602	[illegible].26550	5926.961	9414.336	55.37575	511.2327
C70551.70*	6.265077	28.[illegible]4531	5952.495	9354.207	55.19[illegible]	513.1742
C70551.80*	6.252173	22.65120	5957.121	9292.043	54.75533	515.3525
C70551.90*	6.264106	22.44447	5955.727	9230.270	55.13614	[illegible]15.7134
C70552.00*	6.255111	2[illegible].24354	5947.334	9170.324	55.42215	51[illegible].7575
C70552.10*	6.274933	23.04077	[illegible]48.357	9103.550	55.75035	520.5711
C70552.20*	6.263198	27.3271	5945.430	9047.583	55.72725	522.4413
C70552.30*	6.257214	27.52307	5919.555	8937.719	56.20027	524.3569
C70552.40*	6.254430	27.42345	5937.127	8925.555	55.10503	52[illegible].0725
C70552.50*	6.252435	2[illegible].211[illegible]	5934.175	8855.430	55.4078[illegible]	537.571
C70552.60*	6.251[illegible]77	[illegible]	5922.427	8[illegible]1.255	55.2[illegible]321	[illegible].5533
C70552.70*	6.255534	[illegible].72102	5925.137	8733.770	[illegible].11727	[illegible].47[illegible]
C70552.80*	6.2[illegible]7771	2[illegible].57[illegible]1	5921.393	8675.505	55.27617	631.20[illegible]
C70552.90*	6.235540	25.5[illegible]87	5913.574	8613.752	55.75395	535.7511
C70553.00*	6.245214	25.1[illegible]57	5914.130	8551.573	54.75321	535.7205
C70553.10*	6.245333	25.92747	5910.752	8457.102	55.04797	533.4310
C70553.20*	6.243144	25.74215	5909.293	8424.757	55.55325	54[illegible].2157
C70553.30*	6.254439	25.55[illegible]	5905.391	8360.355	55.12071	641.7321
C70553.40*	6.243703	25.[illegible]	5902.457	8297.211	55.09770	543.6355
C70553.50*	6.247[illegible]33	25.105[illegible]3	5193.557	8235.195	55.50672	645.3247
C70553.60*	6.240054	24.[illegible]7527	5[illegible]72.207	8157.432	55.14252	547.3122
C70553.70*	6.227[illegible]	[illegible]4.[illegible]742[illegible]	5191.717	[illegible]102.949	55.[illegible]	54[illegible].5751
C70553.80*	6.225135	24.457[illegible]1	5190.742	8041.172	55.27376	550.3563
C70553.90*	6.225333	24.2[illegible]11	5[illegible]9.273	7975.219	54.54156	652.3122
C70554.00*	6.21[illegible]163	24.025[illegible]	5[illegible]5.41	7913.727	54.75741	653.6622
C70554.10*	6.225[illegible]3	23.30[illegible]	5379.225	7845.150	54.53402	655.3037
C70554.20*	6.227535	23.57[illegible]	5377.923	7793.277	54.97273	556.7315
C70554.30*	6.227152	23.35[illegible]21	5375.5[illegible]2	7714.715	55.19233	65[illegible].5522
C70554.40*	6.221547	23.15[illegible]	5374.527	7649.532	55.2205[illegible]	660.1514
C70554.50*	6.213[illegible]32	2[illegible].93555	5370.714	7536.716	55.31935	661.74[illegible]
C70554.60*	6.257672	[illegible].71445	5357.507	7521.422	55.21773	655.3253
C70554.70*	6.255233	22.41575	5355.175	7454.[illegible]91	55.35132	[illegible]4[illegible].434
C70554.80*	6.225795	22.25[illegible]0	5357.9[illegible]3	7337.524	55.67815	56[illegible].1594
C70554.90*	6.20[illegible]	2[illegible].05102	5355.325	7321.725	55.53775	557.5716

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TIME	CUAZ (DEGREES)	CUEL (DEGREES)	CURC (YARDS)	ALTITUDE (FEET)	S/N	TIVEL (FT/SEC)
070555.00	0.210[illegible]	21.[illegible]	[illegible]	7256.150	56.14355	[illegible]
070555.10	0.209291	21.[illegible]	5952.154	7187.275	55.[illegible]	67[illegible]
070555.20	0.202192	[illegible]	5952.142	7120.273	55.32169	672.4011
070555.30	0.20502	21.13[illegible]	5950.707	7055.711	55.66326	673.9[illegible]
070555.40	0.20239[illegible]	[illegible]	5947.77[illegible]	6987.109	55.72273	67[illegible].41[illegible]
070555.50	0.20[illegible]44	[illegible]	5944.35[illegible]	6918.326	55.78[illegible]	675.9[illegible]
070555.60	0.2[illegible]	[illegible]	5943.567	6851.262	5[illegible].15623	67[illegible].4210
070555.70	0.210[illegible]	[illegible]	5943.934	67[illegible].56	55.67294	67[illegible]
070555.80	0.1[illegible]10[illegible]	1[illegible]	5939.[illegible]1	6717.375	55.[illegible]7575	6[illegible]1.41[illegible]
070555.90	0.20110	1[illegible].[illegible]1[illegible]4	5937.530	6649.09[illegible]	55.56[illegible]	6[illegible].0 1[illegible]
070556.00	0.17[illegible]	1[illegible].[illegible]4[illegible]5	593[illegible].51[illegible]	65[illegible]1.492	55.37[illegible]64	[illegible]4.[illegible]4[illegible]9
070556.10	0.1[illegible]2[illegible]0	1[illegible].[illegible]14[illegible]	5[illegible].[illegible]37	6515.[illegible]25	55.[illegible]77[illegible]	6[illegible].[illegible]101
070556.20	0.202[illegible]42	17.[illegible]	5932.637	6445.[illegible]24	56.014[illegible]	[illegible]7.2[illegible]
070556.30	0.177[illegible]34	1[illegible].[illegible]	5932.537	6370.043	55.4541[illegible]	[illegible].0[illegible]
070556.40	0.19044[illegible]	1[illegible]	592[illegible].230	6311.751	55.[illegible]07[illegible]3	690.0[illegible]
070556.50	0.16535[illegible]	1[illegible]	592[illegible].727	6244.156	55.[illegible]465[illegible]	691.4955
070556.60	0.1775[illegible]7	1[illegible].1[illegible]60[illegible]	5929.230	6175.156	55.52224	69[illegible].7764
070556.70	0.1[illegible]2[illegible]1	17.[illegible]	5924.336	6104.[illegible]71	55.95157	694.2637
070556.80	0.170161	17.[illegible]11	5921.60[illegible]	6033.[illegible]71	57.25738	695.67[illegible]
070556.90	0.161[illegible]	17.[illegible]	[illegible]920.915	5965.5[illegible]	57.13950	[illegible]7.0[illegible]
070557.00	0.1[illegible]	17.[illegible]1[illegible]	5920.91[illegible]	5[illegible].265	57.09051	[illegible]
070557.10	0.178[illegible]	1[illegible].9[illegible]	5920.410	5[illegible]26.[illegible]3[illegible]	55.99151	[illegible]1
070557.20	0.1[illegible]2[illegible]	1[illegible].75[illegible]	5919.9[illegible]	57[illegible].697	55.59074	701.2269
070557.30	0.17[illegible]51	1[illegible]	5917.012	5685.379	57.03653	70[illegible]
070557.40	0.17[illegible]57[illegible]	1[illegible]	5917.00[illegible]	5617.375	57.12337	70[illegible].956[illegible]
070557.50	0.17[illegible]007	1[illegible]	5917.012	5549.074	57.04544	70[illegible].2[illegible]7
070557.60	0.166[illegible]41	1[illegible].[illegible]157[illegible]	5917.007	5478.770	57.11760	70[illegible].5376
070557.70	0.157[illegible]9	1[illegible]	5917.012	541[illegible].465	57.63515	707.[illegible]416
070557.80	0.153704	1[illegible].3494	5914.547	534[illegible].207	61.[illegible]3133	70[illegible].1[illegible]
070557.90	0.152[illegible].5	1[illegible].10[illegible]	5913.105	5271.203	63.[illegible]0159	710.[illegible]
070558.00	0.17[illegible]57	1[illegible].[illegible]1[illegible]	5913.[illegible]4	5[illegible]0[illegible].043	61.7272[illegible]	[illegible]11.5352
070558.10	0.175.[illegible]	1[illegible].[illegible]11	[illegible]913.105	5129.[illegible]79	5[illegible].[illegible]7232	712.7473
070558.20	0.17[illegible]2[illegible]	1[illegible].[illegible]7	5913.590	5059.559	5[illegible].4[illegible]0[illegible]1	71[illegible].[illegible]19
070558.30	0.162[illegible]3[illegible]	1[illegible].14714	5913.594	49[illegible]8.555	61.9[illegible]677	71[illegible].051
070558.40	0.157572	1[illegible]	[illegible]912.1[illegible]5	4917.[illegible]55	6[illegible].31174	[illegible]17.241[illegible]
070558.50	0.1575[illegible]7	1[illegible]	5913.105	4849.551	61.51[illegible]	717.40[illegible]
070558.60	0.1571[illegible]6	1[illegible].4[illegible]	5913.105	47[illegible].2[illegible]0	57.0552[illegible]	71[illegible].541[illegible]
070558.70	0.151[illegible]	1[illegible].1[illegible]	[illegible]913.105	470[illegible].[illegible]30	5[illegible].6[illegible]107	71[illegible]
070558.80	0.14603[illegible]	1.[illegible]44	5914.55[illegible]	463[illegible].1[illegible]0	6[illegible].44425	720.[illegible]
070558.90	0.144[illegible].7	1[illegible]	5913.105	456[illegible].156	64.44702	721.[illegible]65[illegible]
070559.00	0.14517[illegible]	1[illegible]4[illegible]078	5912.413	4494.156	32.72151	72[illegible].[illegible]0
070559.10	0.147[illegible]	12.2[illegible]	5915.594	442[illegible].154	[illegible]0.22267	724.201[illegible]
070559.20	0.147135	11.[illegible]040	5915.547	4351.160	[illegible]0.0[illegible]	725.[illegible]
070559.30	0.1[illegible]047[illegible]	11.[illegible]	5915.5[illegible]5	42[illegible].175	63.73734	[illegible]26.3774
070559.40	0.13115[illegible]	11.[illegible]7	5917.500	4209.175	6[illegible].[illegible]0014	727.442[illegible]
070559.50	0.1[illegible]3[illegible]	11.[illegible]	5912.[illegible]77	413[illegible].453	65.1[illegible]1[illegible]0	72[illegible].5[illegible]
070559.60	0.14[illegible]0[illegible]	11.[illegible]	5916.5[illegible]	4[illegible]65.133	[illegible].[illegible]9523	729.533[illegible]
070559.70	0.1[illegible]2[illegible]0	1[illegible].[illegible]6[illegible]	[illegible]917.[illegible]	[illegible]994.131	6[illegible].09750	[illegible]30.[illegible]41[illegible]
070559.80	0.1[illegible]1[illegible]0	1[illegible].[illegible]4[illegible]	591[illegible].473	3[illegible].[illegible]409	[illegible]0.356[illegible]	731.5554
070559.90	0.1[illegible]6[illegible]	10.[illegible]	[illegible]926.4[illegible]	3[illegible]47.[illegible]6[illegible]	[illegible]0.22247	73[illegible].52[illegible]

TIME	CRAB (DEGREES)	[illegible] (DEGREES)	[illegible] (YARDS)	ALTITUDE (FEET)	[illegible]	[illegible] VEL (FT/SEC)
070600.00	6.132751	10.34731	5322.3[illegible]7	3775.337	[illegible].9171	73[illegible].5107
070600.10	6.132675	9.[illegible]2775	5322.379	3702.446	66.71152	734.477[illegible]
070600.20	6.131945	9.954214	5321.436	3631.644	64.73950	735.4272
070600.30	6.133233	9.[illegible]07015	5333.371	3553.503	62.10190	736.[illegible]
070600.40	6.135241	9.049920	5325.737	3454.[illegible]2	60.51235	737.3142
070600.50	6.131313	9.31[illegible]132	5322.730	3411.163	62.33475	73[illegible].2639
070600.60	6.13[illegible]735	[illegible]	5326.77[illegible]	3333.120	63.52645	739.2034
070600.70	6.12534[illegible]	[illegible]5102	5321.7[illegible]	3265.466	61.[illegible]9521	740.1325
070600.80	6.105400	8.0327[illegible]1	5335.50[illegible]	3191.745	59.51474	741.0564
070600.90	6.112203	7.[illegible]427[illegible]	5335.565	3113.703	[illegible]3745	741.[illegible]12
070601.00	6.111421	7.5[illegible]73[illegible]4	533[illegible].00[illegible]	3044.982	53.57[illegible]	742.9072
070601.10	6.107725	7.[illegible]	5340.734	2971.262	54.5[illegible]300	74[illegible].3052
070601.20	6.107[illegible]15	7.111797	5342.60[illegible]	2900.250	57.71392	744.5[illegible]24
070601.30	6.031735	6.[illegible]	5342.37[illegible]	2825.319	5[illegible].[illegible]307	745.5471
070601.40	6.111455	6.524[illegible]65	5342.432	2751.155	56.5553[illegible]	745.4031
070601.50	6.111772	6.[illegible]770[illegible]1	5346.435	2677.125	56.33425	747.[illegible]
070601.60	6.093013	6.173735	5349.23[illegible]	2604.434	5[illegible].99435	743.0[illegible]96
070601.70	6.102251	5.[illegible]25237	5353.145	2535.151	[illegible]4.24003	743.8523
070601.80	6.114[illegible]31	5.[illegible]671	5357.351	2471.331	55.52[illegible]	746.4300
070601.90	6.103375	5.254053	5351.323	2403.592	55.50773	749.[illegible]12
070602.00	6.135335	5.4570[illegible]5	5360.469	2349.246	55.97835	749.5[illegible]22
070602.10	6.120333	5.213215	5552.710	2299.901	55.57513	743.7[illegible]
070602.20	6.112745	4.[illegible]81134	5357.793	2230.555	55.13307	747.5[illegible]
070602.30	6.090715	4.747575	5358.516	2171.597	54.26033	745.7957
070602.40	6.092612	4.501175	5357.031	2106.229	55.94711	743.7032
070602.50	6.0[illegible]4	[illegible]	5345.332	2035.203	54.01276	741.4502
070602.60	6.013[illegible]39	[illegible]	5356.070	1965.377	55.32333	739.3795
070602.70	6.022[illegible]20	[illegible]	5364.07[illegible]	1895.650	53.75037	736.3242
070602.80	5.994[illegible]93	3.41345[illegible]	5[illegible]23.45[illegible]	1822.705	53.49636	734.[illegible]
070602.90	5.951333	3.149275	5977.1[illegible]4	1750.143	54.19457	733.31[illegible]
070603.00	5.917255	2.[illegible]	5999.52[illegible]	1672.225	55.17565	732.7590
070603.10	6.02[illegible]03	2.655[illegible]	5044.547	1597.649	56.40393	733.2[illegible]
070603.20	5.365173	2.350[illegible]34	5100.215	1517.905	60.55737	735.3[illegible]3
070603.30	5.955[illegible]63	2.263[illegible]07	5133.275	1434.650	64.79022	742.5552
070603.40	6.147570	1.797132	5134.199	1345.165	57.67423	755.9175
070603.50	5.979974	1.749142	5137.12[illegible]	1251.537	69.29439	777.2455
070603.60	6.145523	1.322540	5137.12[illegible]	1226.043	52.34495	802.5450
070603.70	6.343717	1.[illegible]1915[illegible]	5137.12[illegible]	1231.733	37.31735	[illegible]24.4360
070603.80	6.123556	1.37[illegible]535	[illegible]137.12[illegible]	1247.714	2[illegible].10783	[illegible]
070603.90	6.126115	1.341125	5137.12[illegible]	1267.919	2[illegible].62494	[illegible]
070604.00	6.132464	1.[illegible]46410	5137.123	1284.022	19.28720	[illegible]50.33[illegible]4
070604.10	6.137273	1.[illegible]39344	5137.127	1299.391	17.63127	793.152[illegible]
070604.20	6.142078	1.355331	5137.125	1311.241	16.76720	770.0051
070604.30	6.144155	1.337576	5137.129	1321.342	15.31035	739.2468
070604.40	6.147204	1.[illegible]39331	5137.129	1330.753	16.38153	709.6487
070604.50	6.143252	1.35[illegible]551	5157.129	1335.329	15.95334	643.1247
070604.60	6.133227	1.[illegible]37310	5137.129	1339.593	15.[illegible]5457	559.5[illegible]69

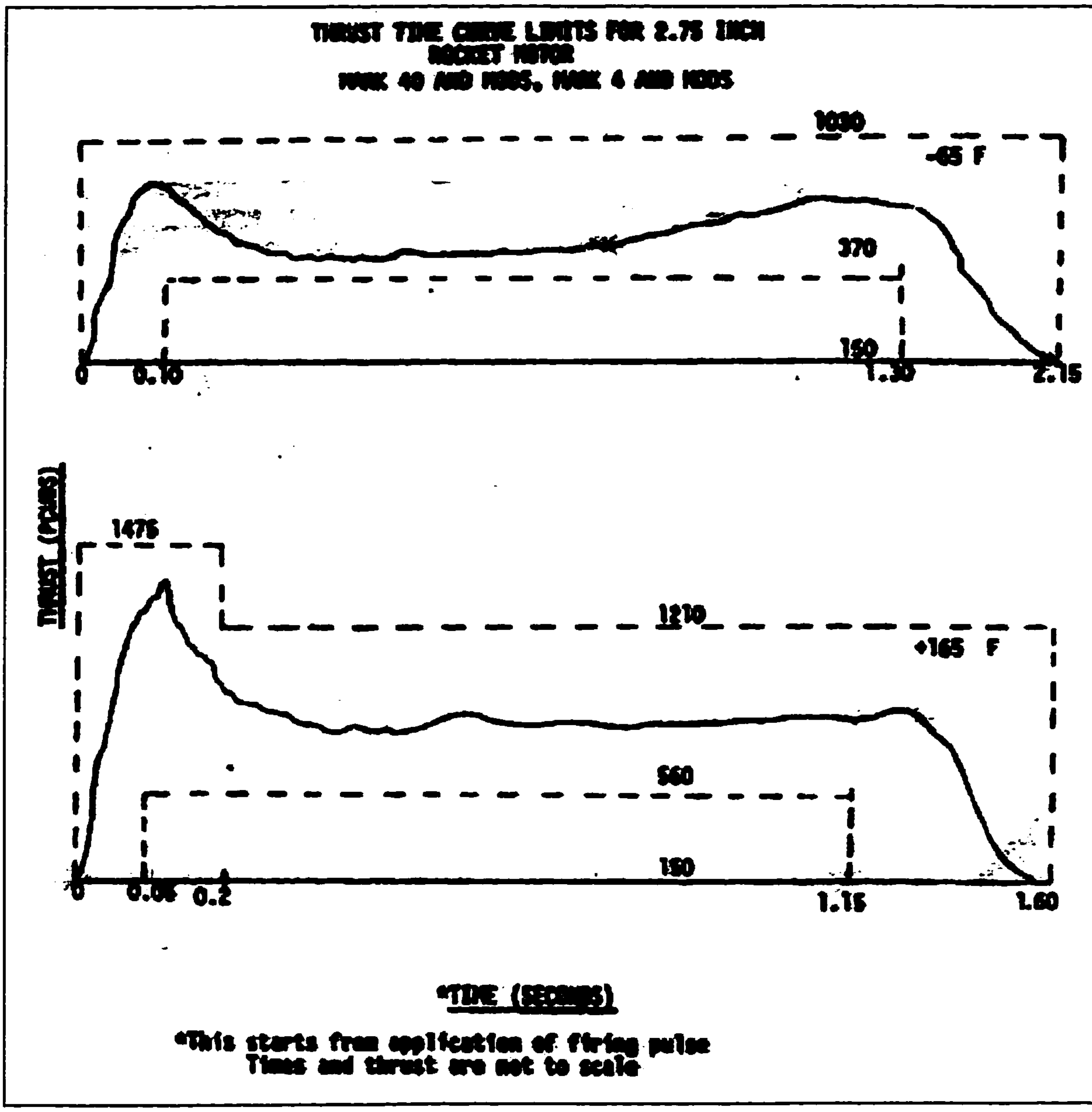
APPENDIX B: Data Sheets

B.1 Data Sheets

MOTOR WITHOUT WARHEAD	Mk 4 (Mk 40)
Loaded Weight	11.22
Burnout Weight	5.2
Weight of Propellant	5.9
Total Length (Fins in folded position)	39.3
Total Length (Fins in open position)	37.4
Maximum Outside Diameter	2.790
Loaded Center of Gravity (From Front End)	18.5
Burnout Center of Gravity (From Front End)	20.2

Motor Type	Total Fin Span (in)	Exit Spin Rate (rps)	Maximum Spin Rate (rps)	Exit Velocity (m/s)	Maximum Acceleration (g)
Mk 40	12.1	1.5	17.5	110.9 ft/sec 33.8	60

Parameters	Mk 4 Mod 6 sc -10° F	Mk 4 Mod 6 sc 70° F	Mk 4 Mod 6 sc 120° F
Action time (s)	1.56	1.54	1.57
Maximum pressure (psia)	1290	1360	1700
Average pressure (psia)	1200	1210	1210
Maximum thrust (lbf)	780	830	1020
Average thrust (lbf)	750	760	760
Total impulse (lbf-s)	1170	1170	1190
Delivered specific impulse (lbf-s/lbm)	—	198	—


THRUST TIME CURVE LIMITS FOR 2.75 INCH
ROCKET MOTOR
MARK 40 AND MODS, MARK 4 AND MODS
1030
-65 F
370
150
0
0.10
1.30
2.15
THRUST (POUNDS)
1475
1210
+165 F
560
150
0
0.08
0.2
1.15
1.60
*TIME (SECONDS)
*This starts from application of firing pulse
Times and thrust are not to scale

APPENDIX C: Gravimetrics

C.1 Motor C.G.

Sara Louise Kralewski

FFAR: Motor and cg calculations;

Time (sec)	Thrust (lbf)	Propellant Weight (lbm)	Motor/Fin Weight (lbm)	C.G. from TNT Motor/Fin C.G. (in)	Nose/payload C.G. (in)	Vehicle C.G. (in)	Vehicle C.G. (ft)
0.00	0	5.900	11.220	29.838	7.125	19.689	1.641
0.08	814	5.700	11.016	29.985	7.125	19.617	1.635
0.08	833	5.633	10.948	30.014	7.125	19.592	1.633
0.10	838	5.567	10.880	30.034	7.125	19.567	1.631
0.18	780	5.300	10.608	30.110	7.125	19.464	1.622
0.20	727	5.233	10.540	30.130	7.125	19.438	1.620
0.29	621	4.933	10.234	30.218	7.125	19.315	1.610
0.33	618	4.817	10.115	30.260	7.125	19.265	1.605
0.81	640	3.200	8.465	30.715	7.125	18.460	1.538
1.12	769	2.187	7.411	31.013	7.125	17.813	1.484
1.16	773	2.087	7.309	31.042	7.125	17.744	1.479
1.30	783	1.667	6.799	31.188	7.125	17.380	1.448
1.35	784	1.400	6.628	31.234	7.125	17.252	1.438
1.77	0	0.000	5.200	31.638	7.125	16.008	1.334

Motor characteristics

Overall

Length (fins folded) (in)	Diameter (in)	Loaded Weight (lb) plus fins
39.3	2.75	11.22
Length (fins open)(in)		Burnout Weight (lb)
37.4		5.2

Nose Length (in)	Payload Length (in)	Distance from TNT to tip (in)	propellant weight burned lb per second
3.6875	6.375	1.375	3.333333333

Nose Weight (lb) 2.003	Payload Weight (lb) 6.649 + flare	Nose/Payload C.G. from tip (in)	Motor/Fin Weight burned lb per second
2.003	7.148	6.75	3.401128944

MOTOR/FIN C.G. (from motor headcap)	FULL (in)	EMPTY (in)
	18.600	20.200

Propellant: Double base solid propellant	Weight (lbm)	Motor/Fin C.G. movement inches per sec
	5.9	0.960

C.2 Weight Summary

Sara Louise Kralewski
FFAR: Mass and Dimension Summary

Component: Nose Cone:	Mass: (lb)	C.G. Location: (inches from TNT)
conical shell (total)	2.847	3.375
truncated end	0.843	1

Aluminum density (lb/in^3)	0.304166667
Steel density (lb/in^3)	0.284

Fin Assy:	mass:	location:
leading edge bevel	0.000	
rectangular part	0.261	47.49
4-fin assy	1.046	47.49

Section #		Mass (lb)	Height (in)	Radius/Width (in)	C.G. Location (inches from TNT)
1	Nose Cone	2.003	3.6875	1.375	4.38
2	Cyl Payload	6.649	6.375	1.125	8.25
3	Flare	0.500	6	0.75	8.4375
4	Fin Assemb	1.046	5.5	1.25	47.49
5	Motor			(from ctr to prop)	
	Time	Mass (lb)	Height (in)	Radius (in)	C.G. Location (from TNT)
	0.00	10.174	33.8	0.5586	28.134
	0.06	9.970	33.8	0.580	28.160
	0.08	9.902	33.8	0.588	28.169
	0.10	9.834	33.8	0.595	28.178
	0.18	9.562	33.8	0.624	28.210
	0.20	9.494	33.8	0.631	28.218
	0.29	9.188	33.8	0.664	28.250
	0.33	9.069	33.8	0.677	28.262
	0.81	7.419	33.8	0.854	28.351
	1.12	6.365	33.8	0.966	28.307
	1.15	6.263	33.8	0.977	28.296
	1.30	5.753	33.8	1.032	28.223
	1.35	5.683	33.8	1.050	28.190
	1.77	4.154	33.8	1.204	27.648

C.3 Longitudinal Moments Of Inertia

Sara Louise Kralewski

TR 1: Pitch Moment Of Inertial Calculations

Vehicle C G (in)	#1 I(L) Nose cone (lb in^2)	#2 I(L) Cyl Payload (lb in^2)	#3 I(L) Flare (lb in^2)	#4 I(L) 4 Fin Assemb (lb in^2)	#5 I(L) Motor (lb in^2)	TOTAL (lb in^2)	TOTAL (lb ft^2)	TOTAL (slug ft^2)
I(L) Individual --->	1.59	26.73	1.57	11.09	973.39			
19.6891	471.34	898.77	64.87	3243.62	1698.93	6376.53	44.27	1.376
19.6169	466.92	885.82	64.06	3260.43	1681.73	6358.96	44.16	1.373
19.5922	465.41	882.10	63.78	3266.19	1675.93	6353.41	44.12	1.371
19.5673	463.89	878.34	63.51	3272.01	1670.11	6347.85	44.08	1.370
19.4644	457.65	862.92	62.37	3296.08	1646.49	6325.52	43.93	1.365
19.4379	456.05	898.98	62.07	3302.30	1640.51	6319.91	43.89	1.364
19.3147	448.65	840.75	60.73	3331.27	1613.12	6294.52	43.71	1.359
19.2650	445.68	833.45	60.19	3342.89	1602.27	6284.58	43.64	1.357
18.4603	398.98	719.89	51.80	3535.69	1436.85	6143.21	42.66	1.326
17.8134	363.31	634.83	45.52	3694.53	1311.19	6049.39	42.01	1.306
17.7444	359.60	626.09	44.88	3711.68	1297.93	6040.18	41.95	1.304
17.3805	340.38	581.02	41.56	3802.79	1228.16	5993.91	41.62	1.294
17.2519	333.71	565.52	40.42	3835.24	1203.51	5978.41	41.52	1.291
16.0063	272.57	426.74	30.21	4156.77	961.97	5848.26	40.61	1.282

C.4 Radial Moment Of Inertia

Sara Louise Kralewski

TR 1: Moment Of Inertial Calculations

SECTION #	INDIVIDUAL MOMENT
#1 I(H) Nose cone (lb in^2)	1.14
#2 I(H) Cyl Payload (lb in^2)	8.42
#3 I(H) Flare (lb in^2)	0.14
#4 I(H) 4 Fin Assemb (lb in^2)	38.19
TOTAL I(H) (lb in^2)	47.88

Time (sec)	# 20 I(R) MOTOR (lb in^2)	TOTAL VEHICLE I(R) (lb in^2)	TOTAL VEHICLE I(R) (lb ft^2)	TOTAL VEHICLE I(R) (slug ft^2)
0.00	9.51	57.39	0.3985	0.01239
0.06	9.53	57.41	0.3987	0.01239
0.08	9.54	57.41	0.3987	0.01239
0.10	9.54	57.42	0.3987	0.01240
0.18	9.55	57.43	0.3988	0.01240
0.20	9.56	57.43	0.3988	0.01240
0.29	9.55	57.43	0.3988	0.01240
0.33	9.55	57.42	0.3988	0.01240
0.81	9.21	57.09	0.3965	0.01232
1.12	8.72	56.60	0.3931	0.01222
1.15	8.66	56.54	0.3927	0.01221
1.30	8.33	56.21	0.3903	0.01213
1.35	8.21	56.09	0.3895	0.01211
1.77	6.91	54.78	0.3804	0.01183

APPENDIX D: Rogers Aeroscience Rocket Performance Software

D.1 Rogers Input

D.1.1 Motor

```
ALT4.05e MOTOR module

  Designation: MK40                  Data date: 02-05-98   Time    Thrust(lbs)
  Mfg. by....: INDIAN HEAD               Cost: ________
  Grain type.: INTERNAL BURN-CYLINDRCAL                    0.00       0.01
  Propellant.: DOUPLE-BASE SOLID                           0.06     914.00
  Diameter...: 2.75     Length: 33.8                       0.08     933.00
    Wgt units: Lbs.      Specs: Thrust curve               0.10     938.00
  Weight Prop: 5.9      Total.: 10.174    mfrac .580       0.18     780.00
  Burn Time..: 1.77     sec                                0.20     727.00
  Avg Thrust.: 622.632 lbs      2769.47   newtons          0.29     621.00
  Tot Impulse: 1102.06 lb/sec   4901.96   newton/sec       0.33     618.00
          ISP: 186.78  Rating: 4902-L-2769                 0.81     649.00
                                91% L                      1.12     769.00
  Remarks:                                                 1.30     783.00
   FOLDING FIN AIRCRAFT ROCKET WITH MK40 MOTOR             1.35     764.00
   SARA LOUISE KRALEWSKI                                   1.77       0.00

  Enter thrust, pounds.

 ESC - MENU                                          F10 - Isp Calc.
```

D.1.2 CD2

```
CD 4.05
   New Run  Edit Current  Printspooler   Quit        Storage

 NAME: FFAR
 DESC: FFAR WITH MK40 MOTOR
 BODY: Maximum diameter.: 2.75      NOSECONE TYPE...........: C
       Overall length...: 47.46        Length...............: 3.6875

 FINS: Number of........: 4         LAUNCH LUG. outside dia.: ______
             Area method.: S
    Root chord.........: 1.25       BOATTAIL: Base diameter.: ______
    Tip  chord.........: 1.25                 length......: ______
    Dist to front of Tc: 3.6
    Fin span ..........: 4.15       NOZZLE exit diameter....: 3.25


    Exposed area.......: 5.2875      Overall representative subsonic CD
    Total equiv area...: 6.90625     (Avg of CD at RN of 10^6 and 10^7)
    Leading edge sweep.: 40.94186                           .3235046

    Airfoil section ...: H
    Diamond airfoil len: .22175
    Fin thickness......: .125
 RETURN - gen data  / F1 - Top /  UpArrow - Last field
```

D.1.3 ALT4

```
YY  ALT4.05e Flight Data   YYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYY

 ¤   Rocket Name: FFAR                                                   ¤
 ¤       Remarks: FFAR WITH MK40 MOTOR                 #   Motor         ¤
 ¤                                                                       ¤
 ¤  Max Diameter: 2.75                                 : 1   MK40      • ¤
 ¤Overall Length: 47.4625                                                ¤
 ¤ Len/Dia ratio: 17.25                                                  ¤
 ¤                                                                       ¤
 ¤   Drag method: F CD File: FFAR                                        ¤
 ¤   Launch Lug?: _ Rcht CD:(____)        Launch wgt: 20.372             ¤
 ¤      Average Subsonic CD: .324                Max: ________           ¤
 ¤                                              Incr: ______             ¤
 ¤ Launch site conditions                                                ¤
 ¤ Elevation(ft): 647       Ground launch ? (Y/N)  : Y                   ¤
 ¤ Air press(Hg): _______      air start altitude  : ______              ¤
 ¤ Air temp. (F): 10           air start velocity  : ______              ¤

Initial Thrust:  .01 lbs. Initial motor weights:  10.174 lbs.
•                                                                         •
•                                                                         •
•                                                                         •
ESC = MENU
```

D.2 Rogers Output

D.2.1 CD Data

```
YY CD2          Data Browser YYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYYY
  ------------->>>>>>>   CD2 by ROGERS AEROSCIENCE   <<<<<<<---------------
                   copyright 1989   by Charles E. Rogers

  All component CD's are based on max body frontal area, and are summed to
  produce the total rocket CD.
  The fin drag (friction and form drag) is mostly friction drag, and is
  referred to as fin friction drag.
  Interference drag is caused by the mounting of the fins on the body of
  the rocket.
  Power ON CD - Total CD less reductions from high pressure gas exhaust and
  is a function of nozzle exit area; boattail configuration; and Mach number.

  Rocket: FFAR        run date: 03-25-19

  Vel  Mach     Total     Power   Fin    Fin    Body   Body   Reynolds Base   LLug
 (fps) Number   CD        ON CD   Frctn  Intrf  Frctn  Press  Number   Drag   Drag
-------------------------------------------------------------------------------
   0   .000   (both infinite)   FINS: laminar  BODY: laminar
  11   .010   .42482   .35499  .1337  .0443  .1742  .0039    267665 .0687  .0000
         -------->  BODY TRANSITIONING TO PARTLY TURBULENT FLOW <-------
  22   .020   .34423   .27439  .0946  .0313  .1381  .0031    535331 .0772  .0000
  33   .030   .35755   .28772  .0772  .0256  .1838  .0041    802996 .0669  .0000
  44   .040   .35940   .28957  .0669  .0222  .2021  .0045   1070662 .0638  .0000
Command                            Up/Dn/PgUP/PgDn/Home/End (ESC-quit browse)
```

D.2.2 ALT4 Data

D.2.2.1 ALT4 Summary

ALT 4.05e by ROGERS AEROSCIENCE Flight report for: FFAR

TIME (sec)	Thrust (lbs)	Drag Coeff.	Accel. (ft/sec2)	Velocity (ft/sec)	Speed of Sound	Mach No.	Velocity (mph)	Altitude (feet)
30.46	0.00	99.999	-32.121	-0.228	989.866	-.000	-0.2	17200.102

```
Lift-off weight ..        20.37 lbs
Max altitude .....    17,200.10 ft.       3.26 miles
max mach number ..         1.68
max velocity .....     1,777.78 ft/sec. at     1.68 sec. (1,212.12 mph)
max acceleration .        45.85 G's     at     0.11 sec.
max deceleration .       -14.26 G's     at     1.78 sec.
     burnout alt .     1,734.07 ft      at     1.77 sec. (calc step: 0.01 sec.)
burnout velocity .     1,760.09 ft/sec (local Mach  1.668) (1200.06 mph)
      coast time .        28.69 seconds
```

Return = data browser;   Q = quit:

D.2.2.2 ALT4 Total Data

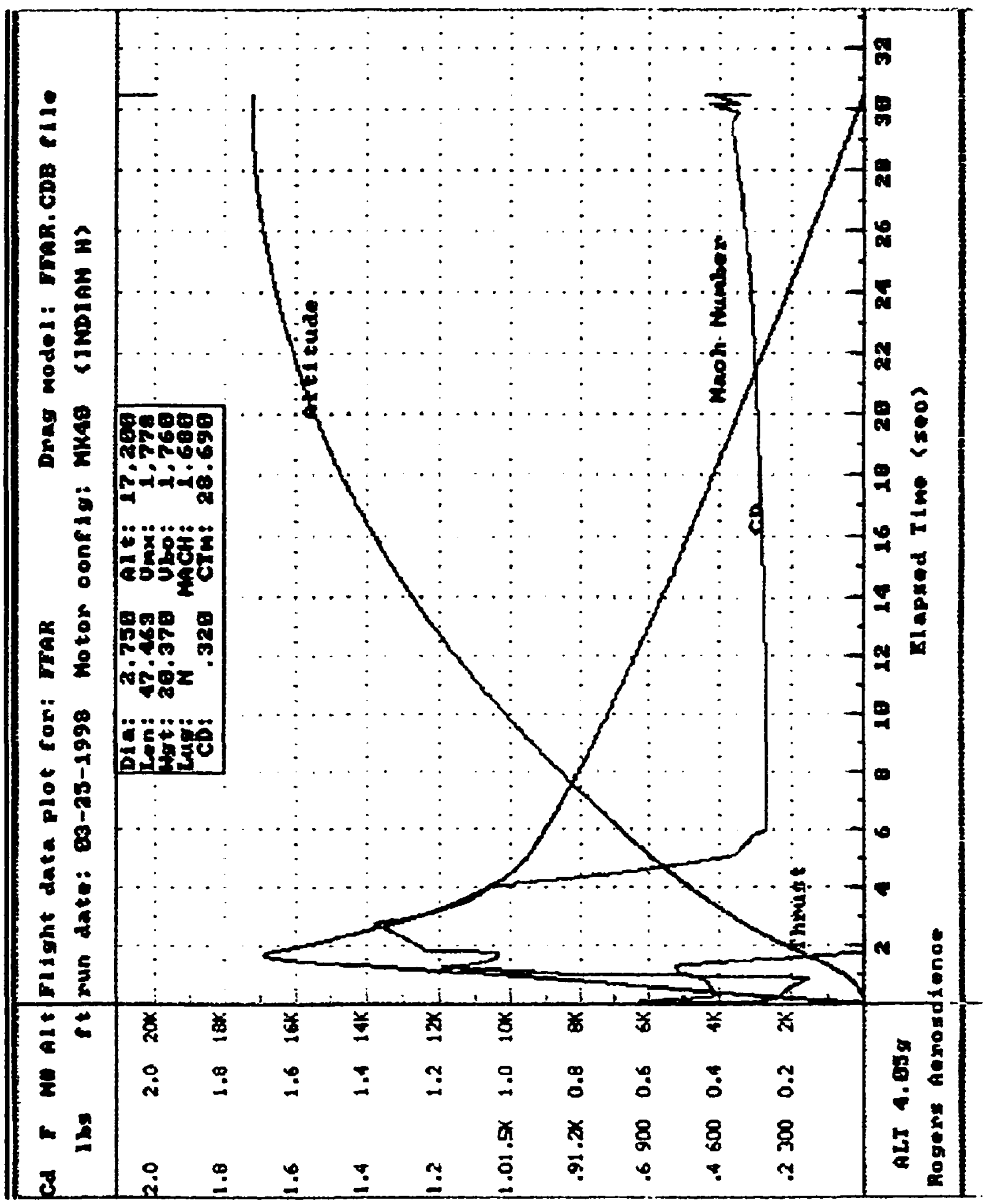
ALT4 TEXT data browser

Flight simulation for: FFAR 03-25-1998 12:59:46

TIME (sec)	Thrust (lbs)	Drag Coeff.	Accel. (ft/sec2)	Velocity (ft/sec)	Speed of Sound	Mach No.	Velocity (mph)	Altitude (feet)
0.00	0.01	N/A	0.000	0.000	1062.403	0.000	0.0	0.000
0.01	152.34	99.999	0.000	0.000	1062.403	0.000	0.0	0.000
0.02	304.67	0.354	208.423	2.084	1062.407	0.002	1.4	0.010
0.03	457.01	0.336	449.197	6.576	1062.407	0.006	4.5	0.054
0.04	609.34	0.307	690.453	13.481	1062.407	0.013	9.2	0.154
0.05	761.67	0.334	932.481	22.806	1062.406	0.021	15.5	0.335
0.06	914.00	0.276	1175.580	34.561	1062.406	0.033	23.6	0.622
0.07	923.50	0.289	1420.036	48.762	1062.404	0.046	33.2	1.039
0.08	933.00	0.289	1438.664	63.149	1062.403	0.059	43.1	1.598
0.09	935.50	0.284	1457.412	77.723	1062.400	0.073	53.0	2.303
0.10	938.00	0.279	1465.078	92.374	1062.397	0.087	63.0	3.153
0.11	918.25	0.274	1472.784	107.103	1062.394	0.101	73.0	4.151
0.12	898.50	0.269	1444.739	121.550	1062.390	0.114	82.9	5.294
0.13	878.75	0.264	1416.468	135.715	1062.385	0.128	92.5	6.580
0.14	859.00	0.260	1387.978	149.596	1052.380	0.141	102.0	8.007
0.15	839.25	0.257	1359.266	163.189	1062.374	0.154	111.3	9.571
0.16	819.50	0.253	1330.344	176.493	1062.368	0.166	120.3	11.269
0.17	799.75	0.250	1301.210	189.505	1062.361	0.178	129.2	13.099
0.18	780.00	0.247	1271.868	202.225	1062.354	0.190	137.9	15.058

Command   Up/Dn/PgUP/PgDn/Home/End (ESC=quit browse)

D.2.3 Rplot



Flight data plot for: FFAR
Drag model: FFAR.CDB file
run date: 03-25-1998
Motor config: MK40 (INDIAN H)
Dia: 2.750
Len: 47.463
Wgt: 20.370
Lug: N
CD: .320
Alt: 17,200
Vmx: 1,778
Vbo: 1,760
MACH: 1.680
CTm: 28.690
Altitude
Mach Number
CD
Thrust
Elapsed Time (sec)
Cd F M# Alt
lbs ft
ALT 4.05g

APPENDIX E: USAF Stability and Control DATCOM

E.1 DATCOM Input

```
$FLTCON NALPHA = 4.,
         ALPHA  = 0.,2.0,4.0,6.0,
        BETA   = 8.0,
        NMACH  = 1.,
        MACH   = .818,
        ALT    = 975.0,
  $END
  $REFQ   SREF  = 5.94,
        LREF  = 2.75,
        RHR   = 250.0,
        BLAYER = NATURAL,
        XCG   = 18.4725,
 $END
 $AXIBOD  XO    = 1.375,
       TNOSE  = CONICAL,
       LNOSE  = 3.6875,
       DNOSE  = 2.75,
       BNOSE  = .5,
       LCENTR= 40.175,
       DCENTR= 2.75,
       DEXIT  = 3.25,
 $END
 $FINSET1  SECTYP = HEX,
        SSPAN  = 1.375,5.525,
        CHORD  = 1.25,1.25,
        XLE    = 43.6125,
        SWEEP  = 41.,
        STA    = 0.,
        LER    = 2*.0625,
        NPANEL = 4.,
         PHIF  = 0.,90.,180.,270.,
        ZUPPER = 0.05,0.05,
        LMAXU  = 0.25,0.1048,
        LFLATU = 0.5,0.7904,
 $END
 DAMP
 DIM IN
 CASEID SARA LOUISE KRALEWSKI FFAR
  NEXT CASE
```

E.2 DATCOM Output

```
            THE USAF AUTOMATED MISSILE DATCOM * REV 6/93 *
          AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS
                   CONERR - INPUT ERROR CHECKING

0 ERROR CODES - N* DENOTES THE NUMBER OF OCCURENCES OF EACH
ERROR
0 A - UNKNOWN VARIABLE NAME
0 B - MISSING EQUAL SIGN FOLLOWING VARIABLE NAME
0 C - NON-ARRAY VARIABLE HAS AN ARRAY ELEMENT DESIGNATION - (N)
0 D - NON-ARRAY VARIABLE HAS MULTIPLE VALUES ASSIGNED
0 E - ASSIGNED VALUES EXCEED ARRAY DIMENSION
0 F - SYNTAX ERROR

  ****************************** INPUT DATA CARD ******************

 1 $FLTCON   NALPHA = 4.,
 2          ALPHA  = 0.,2.0,4.0,6.0,
 3          BETA   = 8.0,
 4          NMACH  = 1.,
 5          MACH   = .818,
 6          ALT    = 975.0,
 7 $END
 8 $REFQ    SREF   = 5.94,
 9          LREF   = 2.75,
10          RHR    = 250.0,
11          BLAYER = NATURAL,   ** SUBSTITUTING NUMERIC FOR NAME
                                      NATURAL
12          XCG    = 18.4725,
13 $END
14 $AXIBOD  XO     = 1.375,
15          TNOSE  = CONICAL,   ** SUBSTITUTING NUMERIC FOR NAME
                                      CONICAL
16          LNOSE  = 3.6875,
17          DNOSE  = 2.75,
18          BNOSE  = .5,
19          LCENTR= 40.175,
20          DCENTR= 2.75,
21          DEXIT  = 3.25,
22 $END
23 $FINSET1  SECTYP = HEX,      ** SUBSTITUTING NUMERIC FOR NAME
                                      HEX
24          SSPAN  = 1.375,5.525,
25          CHORD  = 1.25,1.25,
26          XLE    = 43.6125,
27          SWEEP  = 41.,
```

```
        STA    = 0.,
        LER    = 2*.0625,
        NPANEL = 4.,
         PHIF   = 0.,90.,180.,270.,
         ZUPPER = 0.05,0.05,
         LMAXU  = 0.25,0.1048,
         LFLATU = 0.5,0.7904,
 $END
DAMP
DIM IN
CASEID SARA LOUISE KRALEWSKI FFAR
 NEXT CASE
```

```
THE USAF AUTOMATED MISSILE DATCOM * REV 6/93 *                CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS                PAGE 1
CASE INPUTS
FOLLOWING ARE THE CARDS INPUT FOR THIS CASE

 $FLTCON  NALPHA = 4.,
        ALPHA  = 0.,2.0,4.0,6.0,
       BETA   = 8.0,
       NMACH  = 1.,
       MACH   = .818,
       ALT    = 975.0,
 $END
 $REFQ    SREF   = 5.94,
       LREF   = 2.75,
       RHR    = 250.0,
       BLAYER = 1.,
       XCG    = 18.4725,
 $END
 $AXIBOD  XO     = 1.375,
       TNOSE  = 0.,
       LNOSE  = 3.6875,
       DNOSE  = 2.75,
       BNOSE  = .5,
       LCENTR= 40.175,
       DCENTR= 2.75,
       DEXIT  = 3.25,
 $END
 $FINSET1 SECTYP = 0.,
        SSPAN  = 1.375,5.525,
       CHORD  = 1.25,1.25,
       XLE    = 43.6125,
       SWEEP  = 41.,
       STA    = 0.,
```

```
        LER    = 2*.0625,
        NPANEL = 4.,
         PHIF  = 0.,90.,180.,270.,
        ZUPPER = 0.05,0.05,
        LMAXU  = 0.25,0.1048,
        LFLATU = 0.5,0.7904,
 $END
 DAMP
 DIM IN
 CASEID SARA LOUISE KRALEWSKI FFAR
 NEXT CASE
```

THE BOUNDARY LAYER IS ASSUMED TO DEVELOP NATURALLY OVER ALL COMPONENTS OF THE CONFIGURATION

0 THE INPUT UNITS ARE IN INCHES. THE SCALE FACTOR IS 1.000

THE USAF AUTOMATED MISSILE DATCOM * REV 6/93 * CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 2

SARA LOUISE KRALEWSKI FFAR

STATIC AERODYNAMICS FOR BODY-FIN SET 1

-------------------------------- FLIGHT CONDITIONS -------------------------
------------- REFERENCE DIMENSIONS ------------

MACH NUMBER	ALTITUDE	VELOCITY	PRESSURE	TEMP	REYNOLDS NUMBER	SIDESLIP ANGLE
	FT	FT/SEC	LB/IN**2	DEG R	1/FT	DEG
.82	975.00	910.04	1.419E+01	515.19	5.629E+06	8.00

ROLL ANGLE	REF. AREA	REF. LENGTH LONG.	REF. LENGTH LAT.	MOMENT REF. CENTER LONG.	MOMENT REF. CENTER VERTICAL
DEG	IN**2	IN	IN	IN	IN
.00	5.940	2.750	2.750	18.472	.000

------- DERIVATIVES (PER DEGREE) -----------------
------ LONGITUDINAL ----- --- LATERAL DIRECTIONAL ---
LONGITUDINAL LATERAL DIRECTIONAL

ALPHA	CN	CM	CA	CY	CLN	CLL
.00	.000	.000	.302	-1.710	10.466	.000

2.00	.423	-2.572	.301	-1.707	10.403	-.011
4.00	.862	-5.273	.297	-1.720	10.463	-.009
6.00	1.279	-7.670	.291	-1.705	10.205	-.010

CNA	CMA	CYB	CLNB	CLLB
2.073E-01	-1.255E+00	-2.601E-01	1.364E+00	0.000E+00
2.156E-01	-1.318E+00	-2.585E-01	1.367E+00	2.989E-03
2.140E-01	-1.272E+00	-2.312E-01	1.132E+00	-3.788E-03
2.026E-01	-1.126E+00	-2.270E-01	1.140E+00	-5.381E-03

ALPHA	CL	CD	CL/CD	X-C.P.
.00	.000	.302	.000	-5.198
2.00	.412	.315	1.308	-6.082
4.00	.840	.356	2.358	-6.114
6.00	1.242	.423	2.934	-5.997

0

PANEL DEFLECTION ANGLES (DEGREES)

FIN SET	FIN 1	FIN 2	FIN 3	FIN 4
1	.00	.00	.00	.00

THE USAF AUTOMATED MISSILE DATCOM * REV 6/93 * CASE 1
AERODYNAMIC METHODS FOR MISSILE CONFIGURATIONS PAGE 3

SARA LOUISE KRALEWSKI FFAR

BODY + 1 FIN SET DYNAMIC DERIVATIVES

-------------------------------- FLIGHT CONDITIONS --------------------------
------------- REFERENCE DIMENSIONS ------------

MACH NUMBER	ALTITUDE FT	VELOCITY FT/SEC	PRESSURE LB/IN**2	TEMP DEG R	REYNOLDS NUMBER 1/FT	SIDESLIP ANGLE DEG
.82	975.00	910.04	1.419E+01	515.19	5.629E+06	8.00

ROLL ANGLE DEG	REF. AREA IN**2	REF. LENGTH LONG. IN	REF. LENGTH LAT. IN	MOMENT REF. CENTER LONG. IN	MOMENT REF. CENTER VERTICAL IN
.00	5.940	2.750	2.750	18.472	.000

------------ DYNAMIC DERIVATIVES (PER DEGREE) --------------------

ALPHA	CNQ	CNAD	CMQ+CMAD
.0	3.332E+00	1.268E+00	-8.51090E+00
2.0	3.357E+00	1.310E+00	-8.58887E+00
4.0	3.389E+00	1.363E+00	-8.68559E+00
6.0	3.427E+00	1.425E+00	-8.80108E+00

1*** END OF JOB ***

APPENDIX F: NASA Wallops Sens5d Trajectory and Wind-Sensitivity Calculations for Unguided Rockets

F.1 Sens5d Input

F.1.1 Data Set #1

```
&DLIST
 GDLATL= 65.12952894,
 LONGL =-147.4882341,
 TZERO = 0.,
 AZERO = 647.41,
 VZERO = 0.,
 DTAI  = 0.1,
 DMAX  = 0.1
/
&BLIST
 NPL   = 1,
 PLM   = 9.2,
 AZGDL = 0,
 NANG  = 1,
 ANG   = 82,
 NLEV  = 19,
  ALTW  = 710.1,850.3,1047.06,1447.2,1647.0,1847.68,2067.44,3647.21
         ,5647.3,7647.1,10647.2,12147.8,13647.31,15147.7,16647.3
         ,18647.8,20647.1,23647.99,23147.5,25647.64,
  SPEED = 10.2,15.1,26.3,27.8,27.6,14.4,15.5,30.8,25.2,21.9
         ,31.0,38.8,38.1,40.1,50.3,51.0,62.8,78.1,96.33,
  DIR   = 63.6,66.0,73.1,61.7,69.3,83.3,113.8,-149.6,-155.1
         ,-158.1,123.0,-136.4,-142.1,-145.7,-154.6,-171.1
        ,-179.055,-190.0632,-186.524,
 IROT  = 1,
 IPRINT= 0,
 JSPENT= 0
/
&FLIST
  WPL = 9.2,
  AZGDL = 0,
  ELGDL = 82,
  WIND = 14,
  WNAZ =-140,
  NLEV = 10,
   ALEV = 2000,4000,6000,8000,10000,12000,14000,16000,18000,20000,
  IROT=1,
```

```
  IPRINT = 0.
  IWW=0
 /
&ULIST
 WPL = 9.2.
 AZGDL = 0.
 NANG = 1.
 ANG = 82.
 WIND = 25.
 ALOW = 850.
 AHIGH = 20000.
 IROT = 1.
 IPRINT =0
/
```

F.1.2 Data Set #2

```
FOLDING FIN AICRAFT ROCKET WITH MK40 MOTOR

SARA LOUISE KRALEWSKI

ROCKET WEIGHT. BURN-OUT TIME
 11.22. 1.77
N. START TIMES FOR PHASES
 2. 0.0. 1.77
N. START TIMES FOR SPENT STAGES
0
N. TABLE OF WEIGHTS FOR SPENT STAGES
0
PHASE NO. 1  BEGINS FFAR THRUSTING
NOZZLE EXIT AREA. LENGTH: NOSE TO NOZZLE. REF. AREA. REF. DIAMETER
 0.226.3.76. 0.04125. 0.2292
N. TIME TABLE FOR THRUST AND PROPELLANT WEIGHT
 14. 0.00. 0.06. 0.08. 0.1. 0.18. 0.2. 0.29. 0.33. 0.81. 1.12
 . 1.15. 1.3. 1.35. 1.77
N. THRUSTS AT SEA LEVEL
 14. 0. 914. 933. 938. 780. 727. 621. 618. 649. 769. 773
 . 783. 764. 0.0
N. PROPELLANT WEIGHTS (NOT MASS)
 14. 5.9. 5.7. 5.633. 5.567. 5.3. 5.233. 4.933. 4.817. 3.2
 . 2.167. 2.067. 1.567. 1.4. 0.0
N. TABLE OF MACH NOS. FOR AXIAL DRAG COEFFS.
 9. .001. .087. .213. .315. .818. 1.168. 1.416. 1.535. 1.681
N. AXIAL DRAG COEFFS.
 9. 1.15. .21. .177. .167. .527. 2.864. 2.301. 2.03. 1.805
```

N, TIME TABLE FOR C.G. (FROM NOSE) DISTANCE AND PITCH MOMENT OF INERTIA
14, 0.00, 0.06, 0.08, 0.1, 0.18, 0.2, 0.29, 0.33, 0.81, 1.12
, 1.15, 1.3, 1.35, 1.77
N, C.G. DISTANCE FROM NOSE
14, 1.641, 1.635, 1.633, 1.631, 1.622, 1.62, 1.61, 1.605
, 1.538, 1.484, 1.479, 1.448, 1.438, 1.334
N, PITCH MOMENTS OF INERTIA
14, 44.278, 44.16, 44.12, 44.08, 43.93, 43.89, 43.71
, 43.64, 42.66, 42.01, 41.95, 41.62, 41.52, 40.61
N, TABLE OF MACH NOS. FOR PITCH DAMPING COEFFS.
9, .001, .087, .213, .315, .818, 1.168, 1.416, 1.535, 1.681
N, PITCH DAMPING COEFFS.
9, 5.8365, 4.7115, 4.8108, 4.9383, 7.9752, 10.8203
, 5.1023, 4.3612, 4.0765
N, TABLE OF MACH NOS. FOR SLOPE-OF-NORMAL FORCE COEFFS.
9, .001, .087, .213, .315, .818, 1.168, 1.416, 1.535, 1.681
N, SLOPE OF NORMAL FORCE COEFFS.
9, .2077, .1919, .1922, .1928, .2156, .2449, .1772, .1663, .1537
N, TABLE OF MACH NOS. FOR C.P. (FROM NOSE) DISTANCES
9, .001, .087, .213, .315, .818, 1.168, 1.416, 1.535, 1.681
N, C.P. DISTANCES FROM NOSE
9, 2.8556, 2.7661, 2.7664, 2.7684, 2.9332, 3.0098, 2.678
, 2.6006, 2.5213
PHASE NO.2 BEGINS. FOLDING FIN AIRCRAFT ROCKET COASTING
NOZZLE EXIT AREA, LENGTH: NOSE TO NOZZLE, REF. AREA, REF. DIAMETER
0.0226, 3.76, 0.04125, 0.2292
N, TIME TABLE FOR THRUST AND PROPELLANT WEIGHT
1, 0.0
N, THRUSTS AT VACUUM
1, 0.0
N, PROPELLANT WEIGHTS (NOT MASS)
1, 0.0
N, TABLE OF MACH NOS. FOR AXIAL DRAG COEFFS.
13, .002, .149, .218, .469, .591, .69
, .774, .851, .926, 1.045, 1.305, 1.654, 1.681
N, AXIAL DRAG COEFFS.
13, 1.031, .2070, .1910, .1640, .1750, .21, .3320, .6520, .997
, 3.728, 2.638, 1.84, 1.805
N, TIME TABLE FOR C.G. (FROM NOSE) DISTANCE AND PITCH MOMENT OF INERTIA
1, 0.0
N, C.G. DISTANCE FROM NOSE
1, 1.334
N, PITCH MOMENTS OF INERTIA
1, 40.61
N, TABLE OF MACH NOS. FOR PITCH DAMPING COEFFS.
13, .002, .149, .218, .469, .591, .69

```
. .774. .851. .926. 1.045. 1.305. 1.654. 1.681
N. PITCH DAMPING COEFFS.
13. 8.3453. 7.4970, 7.5129, 7.7161, 5.1869. 9.7314. 10.2014
. 10.7434. 11.4374. 13.4401, 11.7556. 4.2665. 4.0765
N. TABLE OF MACH NOS. FOR SLOPE-OF-NORMAL FORCE COEFFS.
13. .002, .149. .218. .469. .591, .69
. .774. .851. .926, 1.045, 1.305, 1.654. 1.681
N. SLOPE OF NORMAL FORCE COEFFS.
13. .2001. .1918, .1919, .1941, .1690. .2139. .2183. .2221
. .2274. .2529. .2295. .1561, .1537
N. TABLE OF MACH NOS. FOR C.P. (FROM NOSE) DISTANCES
13. .002, .149. .218, .469, .591, .69
. .774. .851, .926. 1.045, 1.305, 1.654. 1.681
N. C.P. DISTANCES FROM NOSE
13. 2.8138. 2.7666, 2.7677, 2.7787, 2.6034, 2.8796. 2.9004
. 2.9277. 2.9591. 3.0045, 2.9740, 2.5319. 2.5213
```

F.2 Sens5d Output

```
1 SENS-5D CALCULATIONS BEGIN -------------------


 INPUT DATA SET NO. 1

 &DLIST
   GDLATL= 65.12952894.
   LONGL =-147.4882341.
   TZERO = 0..
   AZERO = 647.41.
   VZERO = 0..
   DTAI  = 0.1.
   DMAX  = 0.1
 /
 &BLIST
   NPL   = 1.
   PLM   = 9.2.
   AZGDL = 0.
   NANG  = 1.
   ANG   = 82.
   NLEV  = 19.
    ALTW  = 710.1.850.3.1047.06,1447.2.1647.0.1847.68.2067.44.3647.21
          .5647.3,7647.1,10647.2,12147.8,13647.31,15147.7.16647.3
          .18647.8,20647.1,23647.99,23147.5.25647.64,
    SPEED = 10.2.15.1.26.3.27.8,27.6.14.4,15.5,30.8.25.2.21.9
          .31.0,38.8.38.1,40.1,50.3,51.0.62.8.78.1,96.33.
```

```
   DIR    = 63.6.66.0,73.1,61.7,69.3,83.3,113.8,-149.6,-155.1
          ,-158.1,123.0,-136.4,-142.1,-145.7,-154.6,-171.1
         ,-179.055,-190.0632,-186.524,
  IROT  = 1,
  IPRINT= 1,
  JSPENT= 0
 /
 &FLIST
   WPL = 9.2,
   AZGDL = 0,
   ELGDL = 82,
   WIND = 14,
   WNAZ =-140,
   NLEV = 10,
    ALEV = 2000,4000,6000,8000,10000,12000,14000,16000,18000,20000,
   IROT=1,
   IPRINT = 0,
   IWW=0
  /
 &ULIST
   WPL = 9.2,
   AZGDL = 0,
   NANG = 1,
   ANG = 82,
   WIND = 25,
   ALOW = 850,
   AHIGH = 20000,
   IROT = 1,
   IPRINT =0
  /
1 INPUT DATA SET NO. 2

 FOLDING FIN AICRAFT ROCKET WITH MK40 MOTOR SARA LOUISE
KRALEWSKI
 ROCKET WEIGHT, BURN-OUT TIME
  11.22, 1.77
 N, START TIMES FOR PHASES
  2, 0.0, 1.77
 N, START TIMES FOR SPENT STAGES
  0
 N, TABLE OF WEIGHTS FOR SPENT STAGES
  0
 PHASE NO. 1  BEGINS FFAR THRUSTING
 NOZZLE EXIT AREA, LENGTH: NOSE TO NOZZLE, REF. AREA, REF. DIAMETER
  0.226,3.76, 0.04125, 0.2292
 N, TIME TABLE FOR THRUST AND PROPELLANT WEIGHT
  14, 0.00, 0.06, 0.08, 0.1, 0.18, 0.2, 0.29, 0.33, 0.81, 1.12
  , 1.15, 1.3, 1.35, 1.77
```

N. THRUSTS AT SEA LEVEL
14, 0. 914, 933, 938, 780, 727, 621, 618, 649, 769, 773
, 783, 764, 0.0
N. PROPELLANT WEIGHTS (NOT MASS)
14, 5.9, 5.7, 5.633, 5.567, 5.3, 5.233, 4.933, 4.817, 3.2
, 2.167, 2.067, 1.567, 1.4, 0.0
N. TABLE OF MACH NOS. FOR AXIAL DRAG COEFFS.
9, .001, .087, .213, .315, .818, 1.168, 1.416, 1.535, 1.681
N. AXIAL DRAG COEFFS.
9, 1.15, .21, .177, .167, .527, 2.864, 2.301, 2.03, 1.805
N. TIME TABLE FOR C.G. (FROM NOSE) DISTANCE AND PITCH MOMENT OF INERTIA
14, 0.00, 0.06, 0.08, 0.1, 0.18, 0.2, 0.29, 0.33, 0.81, 1.12
, 1.15, 1.3, 1.35, 1.77
N. C.G. DISTANCE FROM NOSE
14, 1.641, 1.635, 1.633, 1.631, 1.622, 1.62, 1.61, 1.605
, 1.538, 1.484, 1.479, 1.448, 1.438, 1.334
N. PITCH MOMENTS OF INERTIA
14, 44.278, 44.16, 44.12, 44.08, 43.93, 43.89, 43.71
, 43.64, 42.66, 42.01, 41.95, 41.62, 41.52, 40.61
N. TABLE OF MACH NOS. FOR PITCH DAMPING COEFFS.
9, .001, .087, .213, .315, .818, 1.168, 1.416, 1.535, 1.681
N. PITCH DAMPING COEFFS.
9, 5.8365, 4.7115, 4.8108, 4.9383, 7.9752, 10.8203
, 5.1023, 4.3612, 4.0765
N. TABLE OF MACH NOS. FOR SLOPE-OF-NORMAL FORCE COEFFS.
9, .001, .087, .213, .315, .818, 1.168, 1.416, 1.535, 1.681
N, SLOPE OF NORMAL FORCE COEFFS.
9, .2077, .1919, .1922, .1928, .2156, .2449, .1772, .1663, .1537
N. TABLE OF MACH NOS. FOR C.P. (FROM NOSE) DISTANCES
9, .001, .087, .213, .315, .818, 1.168, 1.416, 1.535, 1.681
N. C.P. DISTANCES FROM NOSE
9, 2.8556, 2.7661, 2.7664, 2.7684, 2.9332, 3.0098, 2.678
, 2.6006, 2.5213
PHASE NO.2 BEGINS. FOLDING FIN AIRCRAFT ROCKET COASTING
NOZZLE EXIT AREA, LENGTH: NOSE TO NOZZLE, REF. AREA, REF. DIAMETER
0.0226, 3.76, 0.04125, 0.2292
N, TIME TABLE FOR THRUST AND PROPELLANT WEIGHT
1, 0.0
N, THRUSTS AT VACUUM
1, 0.0
N, PROPELLANT WEIGHTS (NOT MASS)
1, 0.0
N, TABLE OF MACH NOS. FOR AXIAL DRAG COEFFS.
13, .002, .149, .218, .469, .591, .69
, .774, .851, .926, 1.045, 1.305, 1.654, 1.681
N, AXIAL DRAG COEFFS.
13, 1.031, .2070, .1910, .1640, .1750, .21, .3320, .6520, .997

, 3.728, 2.638, 1.84, 1.805
N, TIME TABLE FOR C.G. (FROM NOSE) DISTANCE AND PITCH MOMENT OF INERTIA
1, 0.0
N, C.G. DISTANCE FROM NOSE
1, 1.334
N, PITCH MOMENTS OF INERTIA
1, 40.61
N, TABLE OF MACH NOS. FOR PITCH DAMPING COEFFS.
13, .002, .149, .218, .469, .591, .69
, .774, .851, .926, 1.045, 1.305, 1.654, 1.681
N, PITCH DAMPING COEFFS.
13, 8.3453, 7.4970, 7.5129, 7.7161, 5.1869, 9.7314, 10.2014
, 10.7434, 11.4374, 13.4401, 11.7556, 4.2665, 4.0765
N, TABLE OF MACH NOS. FOR SLOPE-OF-NORMAL FORCE COEFFS.
13, .002, .149, .218, .469, .591, .69
, .774, .851, .926, 1.045, 1.305, 1.654, 1.681
N, SLOPE OF NORMAL FORCE COEFFS.
13, .2001, .1918, .1919, .1941, .1690, .2139, .2183, .2221
, .2274, .2529, .2295, .1561, .1537
N, TABLE OF MACH NOS. FOR C.P. (FROM NOSE) DISTANCES
13, .002, .149, .218, .469, .591, .69
, .774, .851, .926, 1.045, 1.305, 1.654, 1.681
N, C.P. DISTANCES FROM NOSE
13, 2.8138, 2.7666, 2.7677, 2.7787, 2.6034, 2.8796, 2.9004
, 2.9277, 2.9591, 3.0045, 2.9740, 2.5319, 2.5213

1NASA WALLOPS FLIGHT CENTER
WALLOPS ISLAND, VIRGINIA
TRAJECTORY SUMMARY AT BURN-OUT, APOGEE AND IMPACT
VERSION 4.7

VEHICLE = FOLDING FIN AICRAFT ROCKET WITH MK40 MOTOR
SARA LOUISE KRALEWSKI
PAY LOAD = 9.19 LBS
LAUNCH AZ = .00 DEG

WIND = VARIABLE WIND SUPPLIED BY USER
EARTH = ROTATING MODEL
1DetaILED PRINT-OUT OF TRAJECTORY FOR LAUNCH ELEVATION = 82.00 DEG
UNITS ARE F-P-S-DEGREE, EXCEPT RANGE(NM) AND ACC(G0).

TM	RG	BEAR	ALT	EL	AZ	ACC	M#	TST	DG	D/PRES	WT	WDN	WDE
.00	.00	180.00	647.	80.56	360.00	.1	.00	21.	0.	0.	20.4	.0	.0
.00	.00	180.00	647.	80.20	360.00	.2	.00	23.	0.	0.	20.4	.0	.0
.00	.00	180.00	647.	79.86	360.00	.3	.00	25.	0.	0.	20.4	.0	.0

.00	.00	180.00	647.	79.54	360.00	.4	.00	28.	0.	0.	20.4	.0	.0
.00	.00	180.00	647.	79.24	360.00	.5	.00	30.	0.	0.	20.4	.0	.0
.00	.00	180.00	647.	78.97	360.00	.6	.00	33.	0.	0.	20.4	.0	.0
.00	.00	180.00	647.	78.72	360.00	.7	.00	35.	0.	0.	20.4	.0	.0
.00	.00	180.00	647.	78.50	360.00	.8	.00	37.	0.	0.	20.4	.0	.0
.00	.00	180.00	647.	78.31	360.00	1.0	.00	40.	0.	0.	20.4	.0	.0
.00	.00	180.00	647.	77.72	360.00	2.0	.00	61.	0.	0.	20.4	.0	.0
.00	.00	180.00	647.	77.76	360.00	2.2	.00	66.	0.	0.	20.4	.0	.0
.00	.00	180.00	647.	77.84	360.00	2.5	.00	71.	0.	0.	20.4	.0	.0
.00	.00	180.00	647.	77.94	360.00	2.7	.00	75.	0.	0.	20.4	.0	.0
.00	.00	180.00	647.	78.05	360.00	2.9	.00	80.	0	0.	20.4	.0	.0
.00	.00	180.00	647.	78.17	360.00	3.2	.00	85.	0.	0.	20.4	.0	.0
.01	.00	180.00	647.	78.30	360.00	3.4	.00	90.	0.	0.	20.4	.0	.0
.01	.00	180.00	647.	78.42	360.00	3.6	.00	94.	0.	0.	20.4	.0	.0
.01	.00	180.00	647.	78.55	360.00	3.9	.00	99.	0.	0.	20.4	.0	.0
.01	.00	180.00	647.	79.46	360.00	6.0	.00	142.	0	0.	20.4	.0	.0
.01	.00	180.00	647.	79.62	360.00	6.4	.00	152.	0.	0.	20.4	.0	.0
.01	.00	180.00	647.	79.75	360.00	6.9	.00	161.	0.	0.	20.4	.0	.0
.01	.00	180.00	647.	79.88	360.00	7.4	.00	171.	0.	0.	20.4	.0	.0
.01	.00	180.00	647.	79.99	360.00	7.8	.00	180.	0.	0.	20.4	.0	.0
.01	.00	180.00	647.	80.09	360.00	8.3	.00	190.	0.	0.	20.4	.0	.0
.01	.00	180.00	647.	80.19	360.00	8.8	.00	199.	0.	0.	20.4	.0	.0
.01	.00	180.00	647.	80.27	360.00	9.3	.00	209.	0.	0.	20.4	.0	.0
.01	.00	180.00	647.	80.35	360.00	9.7	.00	218.	0.	0.	20.4	.0	.0
.02	.00	180.00	647.	80.83	360.00	13.9	.00	304.	0.	0.	20.3	.0	.0
.02	.00	180.00	647.	80.91	360.00	14.9	.00	323.	0.	0.	20.3	.0	.0
.02	.00	180.00	647.	80.97	360.00	15.8	.00	342.	0.	0.	20.3	.0	.0
.02	.00	180.00	647.	81.03	360.00	16.8	.01	361.	0.	0.	20.3	.0	.0
.02	.00	180.00	647.	81.08	360.00	17.7	.01	380.	0.	0.	20.3	.0	.0
.03	.00	180.00	647.	81.12	360.00	18.6	.01	399.	0.	0.	20.3	.0	.0
.03	.00	180.00	647.	81.17	360.00	19.6	.01	418.	0.	0.	20.3	.0	.0
.03	.00	180.00	647.	81.20	360.00	20.5	.01	437.	0.	0.	20.3	.0	.0
.03	.00	180.00	648.	81.24	360.00	21.5	.01	456.	0.	0.	20.3	.0	.0
.04	.00	180.00	648.	81.45	360.00	30.0	.02	628.	0.	0.	20.3	.0	.0

TM	RG	BEAR	ALT	EL	AZ	ACC	M#	TST	DG	D/P	WT	WDN	WDE
.04	.00	180.00	648.	81.49	360.00	31.9	.02	666.	0.	1	20.3	.0	.0
.05	.00	180.00	648.	81.52	360.00	33.8	.02	704.	0.	1.	20.2	.0	.0
.05	.00	180.00	648.	81.54	360.00	35.7	.02	742.	0.	1.	20.2	.0	.0
.05	.00	180.00	648.	81.56	360.00	30.	.03	780.	0.	1.	20.2	.0	.0
.05	.00	180.00	648.	81.59	360.00	33.	.03	818.	0.	1.	20.2	.0	.0
.06	.00	180.00	648.	81.60	360.00	36.	.03	856.	0.	1.	20.2	.0	.0
.06	.00	180.00	648.	81.62	360.00	40.	.04	894.	0.	2.	20.2	.0	.0
.06	.00	180.00	648.	81.64	360.00	43.	.04	926.	0.	2.	20.2	.0	.0
.08	.00	180.00	649 .	81.70	360.00	45.6	.06	940.	0.	5.	20.1	.0	.0
.08	.00	180.00	649.	81.71	360.00	69.	.06	942.	0.	6.	20.1	.0	.0
.08	.00	180.00	649.	81.71	360.00	73.	.07	944.	0.	6.	20.1	.0	.0

.08	.00	180.00	650.	81.72	360.00	76	.07	945.	0.	7.	20.1	.0	.0
.09	.00	180.00	650.	81.72	360.00	80.	.07	945.	0.	7	20.1	.0	.0
.09	.00	180.00	650.	81.73	360.00	84.	.08	946.	0.	8.	20.1	.0	.0
.09	.00	180.00	650.	81.73	360.00	87.	.08	947.	0.	9.	20.1	.0	.0
.09	.00	180.00	650.	81.74	360.00	91.	.08	947.	0.	10.	20.1	.0	.0
.10	.00	180.00	651.	81.74	360.00	95.	.09	948.	0.	10	20.1	.0	.0
.12	.00	180.00	654.	81.76	360.00	135.	.12	904.	0.	21.	20.0	.0	.0
.13	.00	180.00	654.	81.77	360.00	138.	.12	899.	0.	22.	20.0	.0	.0
.13	.00	180.00	654.	81.77	360.00	142.	.13	894.	0.	24	20.0	.0	.0
.13	.00	180.00	655.	81.77	360.00	146.	.13	889.	0.	25.	20.0	.0	.0
.13	.00	180.00	655.	81.77	360.00	149.	.13	884.	0.	26.	20.0	.0	.0
.14	.00	180.01	656.	81.77	360.00	152.	.14	879.	0.	27.	20.0	.0	.0
.14	.00	180.01	656.	81.77	360.00	156.	.14	874.	0.	28.	19.9	.0	.0
.14	.00	180.01	656.	81.77	360.00	159.	.14	869.	0.	30.	19.9	.0	.0
.14	.00	180.02	657.	81.77	360.00	163.	.15	864.	0.	31.	19.9	.0	.0
.17	.00	359.99	661.	81.78	360.00	193.	.17	820.	0.	43.	19.9	.0	.0
.17	.00	360.00	662.	81.78	360.00	199.	.18	810.	0.	46.	19.8	.0	.0
.18	.00	360.00	663.	81.78	360.00	205.	.18	800.	0.	49.	19.8	.0	.0
.18	.00	360.00	664.	81.78	360.00	212.	.19	790.	0.	52.	19.8	.0	.0
.19	.00	360.00	665.	81.78	360.00	218.	.20	777.	0.	55.	19.8	.0	.0
.20	.00	360.00	667.	81.78	360.00	230.	.21	750.	0.	62.	19.8	.0	.0
.20	.00	360.00	668.	81.78	360.00	233.	.21	744.	0.	63.	19.7	.0	.0
.20	.00	360.00	668.	81.78	360.00	236.	.21	738.	0.	65.	19.7	.0	.0
.20	.00	360.00	669.	81.78	360.00	239.	.21	735.	0.	66.	19.7	.0	.0
.21	.00	360.00	669.	81.78	360.00	242.	.22	732.	0.	68.	19.7	.0	.0
.21	.00	360.00	670.	81.78	360.00	245.	.22	729.	1.	70.	19.7	.0	.0
.23	.00	360.00	676.	81.78	360.00	270.	.24	703.	1.	85.	19.6	.0	.0

TM	RG	BEAR	ALT	EL	AZ	ACC	M#	TST	DG	D/P	WT	WDN	WDE
.24	.00	360.00	677.	81.78	360.00	276.	.25	697.	1.	89.	19.6	.0	.0
.24	.00	360.00	678.	81.78	360.00	281.	.25	691.	1.	92.	19.6	.0	.0
.25	.00	360.00	680.	81.78	360.00	287.	.26	685.	1.	96.	19.6	.0	.0
.25	.00	360.00	681.	81.78	360.00	292.	.26	679.	1.	99.	19.6	.0	.0
.26	.00	360.00	683.	81.78	360.00	298.	.27	673.	1.	103	19.6	.0	.0
.26	.00	360.00	684.	81.78	360.00	303.	.27	667.	1.	107.	19.5	.0	.0
.27	.00	360.00	686.	81.78	360.00	308.	.28	662.	1.	111	19.5	.0	.0
.27	.00	360.00	687.	81.78	360.00	314.	.28	656.	1.	115.	19.5	.0	.0
.33	.00	360.00	706.	81.78	360.00	370.	.33	630.	1.	159	19.3	.0	.0
.33	.00	360.00	708.	81.78	360.00	375.	.34	630.	1.	163	19.3	.0	.0
.34	.00	360.00	710.	81.78	360.00	380.	.34	630.	1.	168.	19.3	.0	.0
.35	.00	360.00	713.	82.32	349.73	390.	.35	631.	1.	170	19.3	-4.6	-9.2
.35	.00	360.00	714.	82.32	349.76	392.	.35	631.	1.	180	19.3	-4.6	-9.3
.35	.00	359.99	715.	82.32	349.78	395.	.36	632.	1.	182.	19.3	-4.6	-9.3
.35	.00	359.99	716.	82.32	349.80	398.	.36	632.	2.	185.	19.2	-4.6	-9.3
.36	.00	359.99	717.	82.32	349.83	400.	.36	632.	2.	187.	19.2	-4.6	-9.4
.36	.00	359.99	718.	82.32	349.85	403	.36	632.	2.	189.	19.2	-4.6	-9.4
.38	.00	359.98	727.	82.30	350.03	426.	.38	634.	2.	212.	19.1	-4.7	-9.7

.39	.00	359.98	730.	82.30	350.06	431.	.39	634.	2.	217.	19.1	-4.	-9.8
.39	.00	359.97	732.	82.30	350.09	436.	.39	634.	2.	222.	19.1	-4.8	-9.9
.40	.00	359.97	734.	82.30	350.12	441.	.40	635.	2.	227.	19.1	-4.8	-9.9
.40	.00	359.96	736.	82.29	350.15	446.	.40	635.	2.	233.	19.1	-4.8	-10.
.41	.00	359.96	738.	82.29	350.18	452.	.41	635.	2.	238.	19.1	-4.9	-10.
.41	.00	359.95	741.	82.29	350.21	457.	.41	636.	2.	244.	19.0	-4.9	-10.
.42	.00	359.95	743.	82.29	350.23	462	.42	636.	2.	249.	19.0	-.9	-10.2
.42	.00	359.94	745.	82.29	350.25	467.	.42	637.	3.	255.	19.	-4.9	-10.3
.47	.00	359.89	767.	82.27	350.40	514.	.46	640.	3.	308.	18.9	-5.2	-11.
.48	.00	359.88	772.	82.27	350.42	525.	.47	641.	4.	321.	18.8	-5.2	-11.
.49	.00	359.86	777.	82.26	350.44	535.	.48	641.	4.	334.	18.8	-5.3	-11
.50	.00	359.85	783.	82.26	350.45	546.	.49	642.	4.	347.	18.8	-5.4	-11
.51	.00	359.84	788.	82.26	350.46	557.	.50	643.	4.	361.	18.7	-5.4	-11
.52	.00	359.82	794.	82.26	350.47	567.	.51	644.	5.	375.	18.7	-5.5	-11
.53	.00	359.81	799.	82.26	350.47	578.	.52	644.	5.	389.	18.7	-5.6	-12
.54	.00	359.79	805.	82.25	350.48	589.	.53	645.	5.	403.	18.6	-5.6	-12
.55	.00	359.78	811.	82.25	350.48	599.	.54	646.	6.	418.	18.6	-5.7	-12
.64	.01	359.66	869.	82.22	350.15	697.	.63	653.	9.	565.	18.3	-6.3	-14
.66	.01	359.63	883.	82.21	349.94	719.	.65	654.	10.	601.	18.2	-6.4	-15
.68	.01	359.61	897.	82.20	349.73	741.	.67	656.	11.	638.	18.	-6.5	-16

TM	RG	BEAR	ALT	EL	AZ	ACC	M#	TST	DG	D/P	WT	WDN	WDE
.70	.01	359.59	912.	82.19	349.52	764.	.69	657.	12.	677	18.1	-6.6	-17
.72	.01	359.57	927.	82.18	349.32	786.	.71	659.	13.	716.	18.0	-6.7	-18
.74	.01	359.55	943.	82.17	349.13	808.	.73	660.	14.	758.	18.0	-6.9	-19
.76	.01	359.53	959.	82.15	348.94	831.	.75	662.	16.	800.	17.9	-7.0	-20
.78	.01	359.51	976.	82.14	348.76	853.	.77	663.	17.	844.	17.8	-7.1	-21
.80	.01	359.50	993.	82.13	348.59	876.	.79	665.	19.	889.	17.8	-7.2	-22
.89	.01	359.46	1076.	82.09	348.68	980.	.88	697.	44.	1110.	17.5	-8.0	-25
.90	.01	359.46	1086.	82.09	348.86	992.	.89	701.	48.	1136.	17.4	-8.2	-25
.91	.01	359.46	1095.	82.09	349.04	1004.	.90	705.	53.	1163.	17.4	-8.3	-25
.92	.01	359.47	1105.	82.09	349.23	1015.	.91	709.	57.	1190.	17.4	-8.5	-25
.93	.01	359.47	1116.	82.10	349.42	1027.	.93	713.	62.	1217	17.3	-8.6	-25
.94	.01	359.47	1126.	82.10	349.62	1039.	.94	717.	67.	1245.	17.3	-8.7	-25
.95	.01	359.48	1136.	82.10	349.81	1051.	.95	721.	73.	1273.	17.3	-8.9	-25
.96	.01	359.49	1147.	82.10	350.02	1062.	.96	725.	78.	1330.	17.2	-9.0	-25
.97	.01	359.50	1157.	82.10	350.22	1074.	.97	729.	84.	1330.	17.2	-9.2	-25
1.06	.01	359.66	1257.	82.09	352.24	1179.	1.06	765.	142.	1598	16.9	-10.6	-24
1.77	.04	3.16	2317.	80.72	3.55	1615.	1.46	263	200	2889.	14.5	9.5	-9.5
2.01	.05	3.63	2689.	80.41	4.67	1464.	1.32	0	150	2347.	14.5	14.2	-2.5
3.00	.08	4.44	3868.	78.85	9.58	1032.	.93	0.	53.	1118.	14.5	26.2	15.0
4.11	.11	4.93	4927.	78.31	9.34	918	.83	0.	20.	858.	14.5	24.2	12.4
5.03	.14	5.19	5729.	77.92	8.98	858.	.78	0.	11.	731.	14.5	22.8	10.5
6.07	.17	5.40	6578.	77.43	8.79	805.	.73	0.	7.	627.	14.5	21.7	9.5
7.03	.19	5.55	7315.	76.95	8.60	762.	.70	0.	5.	549.	14.5	20.7	8.6
8.07	.22	5.67	8069.	76.43	6.94	719.	.66	0.	4.	477.	14.5	19.8	3.4
9.04	.24	5.76	8726.	75.91	4.40	681.	.63	0.	3.	419.	14.5	19.1	-4.1

10.08	.27	5.83	9396.	75.26	1.71	642.	.59	0.	3.	365.	14.5	18.3	-11.7
11.04	.29	5.88	9978.	74.55	359.29	607.56		0.	2.	320.	14.5	17.7	-18.4
12.08	.31	5.93	10570.	73.68	356.77	569..53		0.	2.	277.	14.5	17.0	-25.1
13.04	.34	5.95	11082.	72.43	1.78	536.	.49	0.	2.	239.	14.5	20.1	-10.7
14.08	.36	5.97	11599.	70.67	7.91	500.	.46	0.	1.	203.	14.5	24.0	7.5
15.04	.39	5.99	12042.	68.72	12.89	468.	.43	0.	1.	174.	14.5	27.3	23.0
16.08	.41	6.01	12486.	66.88	13.81	433.	.40	0.	1.	146.	14.5	28.5	26.0
17.03	.43	6.03	12863.	65.12	13.55	402.	.37	0.	1.	124.	14.5	29.0	25.2
18.07	.46	6.05	13235.	62.93	13.30	369.	.34	0.	1.	102	14.5	29.5	24.3
19.03	.48	6.07	13547.	60.57	13.09	339.	.31	0.	1.	84.	14.5	29.9	23.6
20.07	.50	6.09	13849.	57.55	12.99	308.	.28	0.	1.	67	14.5	30.5	23.3
21.03	.53	6.10	14097.	54.24	12.94	279.	.25	0.	0.	54.	14.5	31.0	23.2
22.07	.55	6.12	14330.	49.97	12.90	250.	.22	0.	0.	42.	14.5	31.5	23.0

TM	RG	BEAR	ALT	EL	AZ	ACC	M#	TST	DG	D/P	WT	WDN	WDE
23.03	.57	6.14	14514.	45.27	12.87	225.	.19	0.	0.	32.	14.5	31.8	22.9
24.07	.60	6.16	14679.	39.16	12.85	199.	1.0	0.	0.	24.	14.5	32.2	22.8
25.03	.62	6.17	14800.	32.42	12.83	178.	.14	0.	0.	18.	14.5	32.4	22.8
26.07	.64	6.19	14898.	23.83	12.83	159.	.12	0.	0.	13.	14.5	32.6	22.7
27.03	.66	6.20	14956.	14.76	12.84	146.	.11	0.	0.	10.	14.5	32.7	22.7
28.07	.69	6.22	14986.	4.04	12.87	138.	.10	0.	0.	8.	14.5	32.8	22.7
28.44	.69	6.23	14988.	.13	12.88	138.	.10	0.	0.	8.	14.5	32.8	22.7
29.04	.71	6.24	14983.	-6.22	12.91	139.	.10	0.	0.	8.	14.5	32.8	22.7
30.04	.73	6.25	14947.	-16.41	12.96	146.	.11	0.	0.	10.	14.5	32.7	22.
31.04	.75	6.27	14880.	-25.66	13.02	160.	.13	0.	0.	13.	14.5	32.6	22.
32.04	.78	6.28	14780.	-33.70	13.08	179.	.15	0.	0.	18.	14.5	32.4	22.8
33.04	.80	6.30	14649.	-40.50	13.15	201.	.17	0.	0.	25.	14.5	32.1	22.
34.04	.82	6.32	14486.	-46.18	13.24	225.	.20	0.	0.	33.	14.5	31.8	23.
35.0	.84	6.33	14291.	-50.91	13.34	251.	.22	0.	0.	42.	14.5	31.4	23.
36.04	.87	6.35	14064.	-54.87	13.46	278.	.25	0.	0.	54.	14.5	30.9	23.
37.04	.89	6.36	13806.	-58.19	13.59	305.	.28	0.	1.	67.	14.5	30.4	23.
38.04	.91	6.38	13517.	-61.00	13.81	333.	.30	0.	1.	81.	14.5	29.9	23.
39.04	.93	6.39	13196.	-63.37	14.13	361.	.33	0.	1.	98.	14.5	29.5	24.
40.04	.95	6.41	12845.	-65.41	14.50	390.	.36	0.	1.	116.	14.5	29.0	25.
41.04	.98	6.43	12464.	-67.17	14.89	418.	.38	0.	1.	136.	14.5	28.5	26.
42.04	1.00	6.45	12052.	-68.89	14.18	447.	.41	0.	1.	159.	14.5	27.4	23.
43.04	1.02	6.47	11611.	-70.93	9.06	475.	.44	0.	1.	183.	14.5	24.1	7.
44.04	1.04	6.48	11140.	-72.64	3.10	503.	.46	0.	1.	210.	14.5	20.6	-8
45.04	1.06	6.50	10640.	-74.01	356.42	531.	.49	0.	2.	240.	14.5	16.9	-25
46.04	1.08	6.52	10111.	-74.85	358.67	558.	.52	0.	2.	270.	14.5	17.5	-19
47.04	1.10	6.53	9554.	-75.58	1.06	585.	.54	0.	2.	302.	14.5	18.1	-13
48.04	1.13	6.54	8969.	-76.20	3.60	612.	.56	0.	2.	336.	14.5	18.8	-6.
49.04	1.15	6.55	8357.	-76.74	6.27	638.	.59	0.	3.	372.	14.5	19.5	.1
50.04	1.17	6.57	7719.	-77.20	9.05	663.	.61	0.	3.	410	14.5	20.2	7.
51.04	1.19	6.58	7055.	-77.66	9.65	688.	.63	0.	3.	450.	14.5	21.1	8.
52.04	1.21	6.59	6366.	-78.08	9.98	711.	.65	0.	4.	492.	14.5	21.9	9.
53.04	1.23	6.60	5654.	-78.47	10.33	734.	.67	0.	4.	535.	14.5	22.8	11

54.04	1.25	6.61	4920.	-78.77	11.03	755.	.68	0.	5.	580.	14.5	24.2	12
55.04	1.27	6.63	4164.	-79.04	11.75	775.	.70	0.	6.	625.	14.5	25.6	14
56.04	1.29	6.64	3389.	-79.62	10.69	793.	.72	0.	7.	671.	14.5	23.2	10
57.04	1.31	6.66	2596.	-80.81	5.10	809.	.73	0.	8.	717.	14.5	13.0	-4.
58.04	1.32	6.67	1788.	-82.34	358.68	822.	.74	0.	9.	764.	14.5	-4.1	-17.
59.64	1.35	6.69	471.	-82.49	7.32	839.	.75	0.	10.	825.	14.5	.0	.0

TM	RG	BEAR	ALT	EL	AZ	ACC	M#	TST	DG	D/PRES	WT	WDN	WDE
60.04	1.36	6.69	138.	-82.61	7.34	.3	.75	0.	11.	840.	14.5	.0	.0

A P O G E E   B U R N O U T

****

EL (DEG)	TIME (SEC)	ALT (FT)	RANGE (NM)	TIME (SEC)	ALT (FT)	RANGE (NM)	VEL (FT/SEC)	FLT/EL (DEG)	FLT/AZ (DEG)
82.00	28.44	14988.	.7	1.77	2317.	.0	1614.71	81.02	5.83

I M P A C T

****

TIME (SEC)	RANGE (NM)	AZ (DEG)
60.21	1.4	6.70

1NASA WALLOPS FLIGHT CENTER
WALLOPS ISLAND, VIRGINIA
F(Z)-CURVE AND BALLISTIC WIND FACTORS
VERSION 4.7

VEHICLE = FOLDING FIN AICRAFT ROCKET WITH MK40 MOTOR
SARA LOUISE KRALEWSKI
PAY LOAD = 9.19 LBS
LAUNCH EL = 82.00 DEG
LAUNCH AZ = .00 DEG
WIND = 14.00 FT/SEC (4.27 M/SEC)-140.00 DEG AZ FROM NORTH
EARTH = ROTATING MODEL

Z ALT	WIND ALT (FT)	(M)	IMPACT RANGE (NM)	(KM)	F(Z)	DF(Z) F(Z)-F(Z-1)	WIND (FT)	(M)
1	2000.	610.	1.18	2.19	.00000	.00000	2000.	610.
2	4000.	1219.	1.14	2.11	2.17319	2.17319	4000.	1219.

3	6000.	1829.	1.15	2.13	1.71431	-.45889	6000.	1829.
4	8000.	2438.	1.15	2.14	1.50923	-.20508	8000.	2438.
5	10000.	3048.	1.16	2.14	1.36937	-.13986	10000.	3048.
6	12000.	3658.	1.16	2.15	1.24058	-.12879	12000.	3658.
7	14000.	4267.	1.16	2.15	1.10639	-.13419	14000.	4267.
8	16000.	4877.	1.16	2.15	1.00000	-.10639	16000.	4877.
9	18000.	5486.	1.16	2.15	1.00000	.00000	18000.	5486.
10	20000.	6096.	1.16	2.15	1.00000	.00000	20000.	6096.

1NASA WALLOPS FLIGHT CENTER
WALLOPS ISLAND, VIRGINIA
UNIT-WIND EFFECTS, CORIOLIS DEFLECTION AND RANGE DERIVATIVE
VERSION 4.7

VEHICLE = FOLDING FIN AICRAFT ROCKET WITH MK40 MOTOR
SARA LOUISE KRALEWSKI
PAY LOAD = 9.19 LBS
LAUNCH AZ = .00 DEG
WIND = 25.00 FT/SEC (7.62 M/SEC).
EARTH = ROTATING MODEL

F-P-S SYSTEM

LAUNCH EL	NO-WIND IMPACT		CORIOLIS DEFLECTION	
(DEG)	RANGE(NM)	AZ(DEG)	NORTH(NM)	EAST(NM))
82.00	1.18	359.99	-.01	.00

RANGE DERIV	UNIT - WIND EFFECTS		
(NM/DEG)	HEAD(NM/FPS)	TAIL(NM/FPS)	CROSS(NM/FPS)
-.14224	-.00129	.00120	.00090

M-K-S SYSTEM

LAUNCH EL	NO-WIND IMPACT		CORIOLIS DEFLECTION	
(DEG)	RANGE(KM)	AZ(DEG)	NORTH(KM)	EAST(KM))
82.00	2.19	359.99	-.02	.00

RANGE DERIV	UNIT - WIND EFFECTS		
(KM/DEG)	HEAD(KM/MPS)	TAIL(KM/MPS)	CROSS(KM/MPS)
-.26343	-.00785	.00731	.00549

THIS CONCLUDES THE CALCULATION.

APPENDIX G: NASA Langley Research Center LRC- MASS (GEM)

G.1 LRC-MASS (Gem) Input

```
X26$ FOLDING FIN AIRCRAFT ROCKET  SARA KRALEWSKI 6-DOF (02/17/98)
X33$ FFAR (MK40) CG VS TIME
1 0 14 1
 0.0 .06 .08 .1 .18 .2 .29 .33 .81 1.12 1.15 1.3 1.35 1.77
0
1.641 1.635 1.633 1.631 1.622 1.62 1.61 1.605 1.538 1.484
1.479 1.448 1.438 1.334
 $
 X33$ FFAR (MK40) IXX VS TIME
1 0 14 1
0.0 .06 .08 .1 .18 .2 .29 .33 .81 1.12 1.15 1.3 1.35 1.77
 0
 .3985 .3987 .3987 .3987 .3988 .3988 .3988 .3988 .3965
.3931 .3927 .3903 .3895 .3804
 $
X33$ FFAR (MK40) IYY VS TIME
1 0 14 1
0.0 .06 .08 .1 .18 .2 .29 .33 .81 1.12 1.15 1.3 1.35 1.77
 0
44.27 44.16 44.12 44.08 43.93 43.89 43.71 43.64 42.66
42.01 41.95 41.62 41.52 40.61
$
  X33$  FFAR (MK40) WEIGHT VS TIME (LESS PAYLOAD)
1 0 14 1
 0.0 .06 .08 .1 .18 .2 .29 .33 .81 1.12 1.15 1.3 1.35 1.77
 0
11.22 11.016 10.948 10.88 10.608 10.54 10.234 10.115 8.465
 7.411 7.309 6.799 6.628 5.2
$
X33$ FFAR (MK40) THRUST VS TIME
 1 0 14 1
0.0 .06 .08 .1 .18 .2 .29 .33 .81 1.12 1.15 1.3 1.35 1.77
 0
0 914 933 938 780 727 621 618 649 769 773 783 764 0
$
 X23$  FFAR (MK40) CX VS MACH NUMBER
1 0 9 1
  .001 .087 .213 .315 .818 1.168 1.416 1.535 1.681
 0
```

```
1.15 .21 .177 .167 .527 2.864 2.301 2.03 1.805
$
X9$ UNITY TABLE
1 0 2 1  0 999  0  1 1
$
X9$ DUMMY TABLE
1 0 2 1  0 999  0  0 0
$
X23$ FFAR (MK40) CN VS MACH NO.
1 0 9 1
.001 .087 .213 .315 .818 1.168 1.416 1.535 1.681
0
.402 .371 .372 .373 .423 .488 .357 .336 .313
$
X23$ FFAR (MK40) CN-Q VS MACH NO.
1 0 9 1
.001 .087 .213 .315 .818 1.168 1.416 1.535 1.681
0
3.04 2.735 2.762 2.796 3.358 2.859 1.365 1.303 1.254
$
X23$  FFAR (MK40) CM VS MACH NO.
1 0 9 1
.001 .087 .213 .315 .818 1.168 1.416 1.535 1.681
0
2.131 1.837 1.859 1.889 2.572 3.241 1.914 1.722 1.613
$
X23$  FFAR (MK40) CMQ VS MACH NO.
1 0 9 1
.001 .087 .213 .315 .818 1.168 1.416 1.535 1.681
0
16.79 14.18 14.6 14.87 10.01 10.95 8.38 8.02 7.999
$
X23$  FFAR (MK40) CM-ALPHA VS MACH NO.
1 0 9 1
.001 .087 .213 .315 .818 1.168 1.416 1.535 1.681
0
1.103 .9553 .9643 .9776 1.317 1.623 .9391
.8399 .7812
$
X23$  FFAR (MK40) CN-ALPHA VS MACH NO.
1 0 9 1
.001 .087 .213 .315 .818 1.168 1.416 1.535 1.681
0
.2077 .1919 .1922 .1928 .2156 .2449 .1772
.1663 .1537
$
X9$  FFAR (MK40) CG COASTING
1 0 2 1
```

```
 1.77 80
 0
1.334 1.334
  $
 X9$  FFAR (MK40) IXX COASTING
 1 0 2 1
 1.77 80
0
.3429 .3429
$
X9$  FFAR (MK40) IYY COASTING
 1 0 2 1
1.77 80
0
40.6 40.6
$
X9$  FFAR (MK40) WEIGHT COASTING
  1 0 2 1
1.77 80
0
5.2 5.2
$
X9$  FFAR (MK40) THRUST COASTING
 1 0 2 1
1.77 80
0
0 0
  $
X31$  FFAR (MK40) CX COASTING
 1 0 13 1
.002 .149 .218 .469 .591 .69 .774 .851 .926
 1.045 1.305 1.654 1.681
0
 1.031 .207 .191 .164 .175 .21 .332 .652 .977
 3.728 2.638 1.84 1.805
$
X31$  FFAR (MK40) CN COASTING
 1 0 13 1
.002 .149 .218 .469 .591 .69 .774 .851 .926
 1.045 1.305 1.654 1.681
  0
.387 .371 .371 .377 .327 .414 .423 .434
 .446 .499 .46 .318 .313
  $
X31$  FFAR (MK40) CNQ COASTING
  1 0 13 1
.002 .149 .218 .469 .591 .69 .774 .851 .926
  1.045 1.305 1.654 1.681
```

```
 0
3.297 3.117 3.125 3.199 2.619 3.613 3.708
 3.67 3.55 3.539 1.702 1.277 1.254
 $
 X31$ FFAR (MK40) CM COASTING
  1 0 13 1
 .002 .149 .218 .469 .591 .69 .774 .851 .926
    1.045 1.305 1.654 1.681
           0
   2.498 2.319 2.323 2.375 1.811 2.793 2.889
3.016 3.16 3.635 3.29 1.662 1.613
 $
  X31$ FFAR (MK40) CMQ COASTING
 1 0 13 1
.002 .149 .218 .469 .591 .69 .774 .851 .926
1.045 1.305 1.654 1.681
 0
 20.118 18.479 18.74 19.23 13.8 13.57 12.51 12.07
12.29 12.46 12.13 8.14 7.9998
  $
 X31$ FFAR (MK40) CM-ALPHA COASTING
 1 0 13 1
   .002 .149 .218 .469 .591 .69 .774 .851 .926
  1.045 1.305 1.654 1.681
 0
 1.295 1.203 1.203 1.223 .9393 1.444 1.493 1.553
 1.62 1.846 1.633 .8061 .7812
$
 X31$ FFAR (MK40) CN-ALPHA COASTING
 1 0 13 1
  .002 .149 .218 .469 .591 .69 .774 .851 .926
 1.045 1.305 1.654 1.681
 0
 .2001 .1918 .1919 .1941 .169 .2139 .2183 .2221 .2274
  .2529 .2295 .1561 .1537
  $
 X1 0 0 0$
 FFAR MK40 MOTOR 6-D SARA LOUISE KRALEWSKI
TIME(SEC)  ALT(ft)
  X 0 95 28 0 0 0 31$
 6001 20.42      PAYLOAD AND VEHICLE WEIGHT
43 0.0001     MAX TRUNCATION ERROR ALLOWED
 50 1         OBLATE ROTATING EARTH
  51 0         NO WINDS
52 1          '62 STD ATMOSPHERE
 53 .001953125   INITIAL DELTA TIME(SEC)
55 1          THRUST ON
56 0          RUNGE-KUTTA INTEGRATION
```

```
57 1        VARIABLE DELTA T
59 3        BINARY TAPE OUTPUT
 60 1       INPUT BODY RATES
  175 3600      ROLL RATE(DEG/SEC)
 176 2.0       PITCH RATE(DEG/SEC)
  177 0.0       YAW RATE(DEG/SEC)
 61 9.765625E-4  MINIMUM DELTA T
  62 1.0       MAXIMUM DELTA T
64 2        POSITION INPUT OPTION 2
 100 0.      CURRENT TIME
  101 0       INITIAL TIME
 107 65.129     LATITUDE
 106 -147.49     LONGITUDE
 108 647.0      ALTITUDE
 65 4       VELOCITY INPUT OPTION 4
120 1.       VELOCITY
121 82       VELOCITY VECTOR ELEVATION
 122 0.       VELOCITY VECTOR AZIMUTH
 66 2       BODY ORIENTATION INPUT OPTION 2
  138 0.0       BANK ANGLE
 139 82       BODY ELEVATION
 140 0.       BODY AZIMUTH
 67 400000     HEIGHT OF SENSIBLE ATMOSPHERE
68 2        NONLINEAR AERODYNAMICS
70 0        DO NOT USE THIS OPTION
 73 10       TAKE 10 STEPS BEFORE DOUBLING DELTA T
 156 .04125     REFERENCE AREA
 157 .2292      REF DIAMETER
 173 -147.49     REFERENCE LONGITUDE
 174 65.129     REFERENCE LATITUDE
 600 1       STOP WHEN
 601 100       CURRENT TIME
 602 1.77       EQUALS 1 SEC
 650 0       PRINT WHEN
651 100       CURRENT TIME CHANGES BY
 652 0.1       A SECOND
  656 0       WRITE THE OUTPUT TAPE WHEN
  657 100       CURRENT TIME CHANGES BY
658 0.1      A TENTH   OF A SECOND
 701 6       PRINT ON FILE 6
  702 3       NUMBER OF INDICES TO PRINT
 703  100  704  108
 815 2       FREQUENCY ANALYSIS OPTION ON
  817 0.15915494  CONVERT RAD/SEC TO CPS IN FREQUENCY ROUTINE
900 0.0      CONSTANT=ZERO
 901 1.0       CONSTANT=UNITY
902 -1.0      MULTIPLIER
 903 -0.08333333  CONSTANT(FT/IN)
```

```
904 0.0      FIN CANT (RAD)
905 0.0      X WIND
906 0.0      Y WIND
907 0.0      YCG
908 0.       ZCG
909 9.2      PAYLOAD WEIGHT
911 1.0      APACHE THRUST MULTIPLIER
1000 0.      THRUST MISALIGNMENT
1001 90.0    THRUST MISALIGNMENT IN BODY PITCH PLANE
1022 .27083  NOZZLE EXIT AREA
1064 1       THRUST AND WEIGHT RATE OPTION 1
1074 1       WEIGHT OPTION 1
1084 0       ATTITUDE CONTROL OPTION 0
1144 0.0     START TIME FOR BODY MOMENT CALCULATIONS
1145 999     STOP TIME FOR BODY MOMENT CALCULATIONS
1164 1       ONE ROCKET
1208 -4.11   THRUST APPLICATION POINT
1209 0.      Y THRUST OFFSET
1210 0.      Z THRUST OFFSET
1238 77      USE TABLES 77-79 FOR CG POSITIONS
1271 0       COORDINATE OPTION
5000 4       SCALE 4 VARIABLES
5001 175     ROLL RATE IN DEG/SEC
5101 2.7777778E-3 TO ROLL RATE IN CPS
5002 531     PDOT IN DEG/SEC2
5102 2.7777778E-3 TO PDOT IN CYCLES/SEC2
5003 108     ALTITUDE IN FEET
5103 3.048E-4   TO ALTITUDE IN KILOMETERS
5004 578     RANGE IN FEET
5104 1.645788E-4  TO RANGE IN NAUTICAL MILES
5410 1       JET DAMPING ON
5411 0       NO EXTERNAL FORCES
5412 0       NO EXTERNAL MOMENTS
5329 0.      TAIL MISALIGNMENT (RAD)
5498 0       LABELS AT BEGINNING OF PHASE ONLY
5500 3       NUMBER OF INDICES TO WRITE ON TAPE
5501  100 5502  108
$
1 9 7 108  0  0 335  0  905  0 0 0 0 $ WIND X
2 9 7 108  0  0 336  0  906  0 0 0 0 $ WIND Y
3 9 7 108  0  0 337  0  900 -1  0 0 0 $ WIND Z = 0.
4 9 7 108  0  0 338  0  901 -1  0 0 0 $ PRESSURE RATIO
5 9 7 108  0  0 339  0  901 -1  0 0 0 $ DENSITY RATIO
6 9 7 108  0  0 340  0  901 -1  0 0 0 $ SOUND SPEED RATIO
7 9 7 108  0  0 341  0  901 -1  0 0 0 $ VISCOSITY RATIO
16 9 6 401  0  0 417  0  902  0 0 0 0 $ CD THRUSTING
23 9 9 401  0  0 424  0  901  0 0 0 0 $ CN
24 9 10 401  0  0 425  0  901  0 0 0 0 $ CNQ
```

```
25 9 13 401 0 0 426 0 901 0 0 0 0 $ CN ALPHA
 26 9 7 401 0 0 427 0 900 -1 0 0 0 $ CNP ALPHA = 0
 27 9 7 401 0 0 483 0 904 0 0 0 0 $ CL DELTA
28 9 7 401 0 0 484 0 901 0 0 0 0 $ CLP
 31 9 11 401 0 0 487 0 902 0 0 0 0 $ CM
 32 9 12 401 0 0 488 0 902 0 0 0 0 $ CMQ
37 9 14 401 0 0 493 0 902 0 0 0 0 $ CM ALPHA
41 9 5 100 0 0 1042 0 911 0 0 0 0 $ THRUST
61 9 4 100 0 0 1054 0 901 0 0 0 0 $ WEIGHT
 71 9 2 100 0 0 161 0 901 0 0 0 0 $ IXX
 72 9 7 100 0 0 162 0 900 0 0 0 0 $ IXY = 0.
73 9 7 100 0 0 163 0 900 0 0 0 0 $ IXZ = 0.
74 9 3 100 0 0 165 0 901 0 0 0 0 $ IYY
 75 9 7 100 0 0 166 0 900 0 0 0 0 $ IYZ = 0.
  76 9 3 100 0 0 169 0 901 0 0 0 0 $ IZZ
77 9 1 100 0 0 1205 0 901 0 0 0 0 $ XCG
78 9 8 100 0 0 1206 0 907 -1 0 0 0 $ YCG
79 9 8 100 0 0 1207 0 908 -1 0 0 0 $ ZCG
 X 1 1 0 0 $
 COAST TO APOGEE
 X0 8 0 0 0 0 34 $
6001 14.4
55 0
601 121
602 0.
53 1
650 0
 651 100
 652 .1
 $
 X1 1 0 0 $
COAST TO IMPACT
  X0 7 0 0 0 0 34 $
 601 108 602 0.
  650 0
651 100
 652 .1
601 100 602 1220
 $
```

G.2 LRC-MASS (GEM) Output

```
                              ###################################################
#################################################################################
############### ###############WFF Code 840 Local Area VAXcluster - VMS
Version V5.3-1
#################################################################################
#################################################################################
                  GGGGGGGGG  EEEEEEEE    MMM    MMM
                  GGGGGGGGG   EEEEEEEE   MMMM  MMMM
                  GGG         EEE       MMMMMMMMMMMMM
                  GGG  GGGGG  EEEEEEEE  MMM MMM MMM
                  GGG   GGGGG EEEEEEEE   MMM  M    MMM
                  GGG      GGG  EEE        MMM       MMM
                  GGGGGGGGG   EEEEEEEE   MMM       MMM
                  GGGGGGGGG  EEEEEEEE    MMM       MMM

RUN STARTED 5-MAR-1998 13:22:59.11
SRBPO VERSION
ON CLUSTER NODE ACAD5
5.0
#################################################################################
########  INPUT FILE : SYS$USER:[KRALEWSKI]FFARSK4.T;19
#################################################################################
########  OUTPUT FILE: NL:[]FOR020.DAT;
#########################################################################

X26$ FOLDING FIN AIRCRAFT ROCKET  SARA KRALEWSKI 6-DOF (02/17/98)
X33$ FFAR (MK40) CG VS TIME
1 0 14 1
 0.0 .06 .08 .1 .18 .2 .29 .33 .81 1.12 1.15 1.3 1.35 1.77
0
1.641 1.635 1.633 1.631 1.622 1.62 1.61 1.605 1.538 1.484
1.479 1.448 1.438 1.334
 $
 X33$ FFAR (MK40) IXX VS TIME
1 0 14 1
0.0 .06 .08 .1 .18 .2 .29 .33 .81 1.12 1.15 1.3 1.35 1.77
 0
 .3985 .3987 .3987 .3987 .3988 .3988 .3988 .3988 .3965
.3931 .3927 .3903 .3895 .3804
 $
X33$ FFAR (MK40) IYY VS TIME
1 0 14 1
0.0 .06 .08 .1 .18 .2 .29 .33 .81 1.12 1.15 1.3 1.35 1.77
 0
44.27 44.16 44.12 44.08 43.93 43.89 43.71 43.64 42.66
```

```
42.01 41.95 41.62 41.52 40.61
$
 X33$  FFAR (MK40) WEIGHT VS TIME (LESS PAYLOAD)
1 0 14 1
 0.0 .06 .08 .1 .18 .2 .29 .33 .81 1.12 1.15 1.3 1.35 1.77
 0
11.22 11.016 10.948 10.88 10.608 10.54 10.234 10.115 8.465
 7.411 7.309 6.799 6.628 5.2
$
X33$ FFAR (MK40) THRUST VS TIME
 1 0 14 1
0.0 .06 .08 .1 .18 .2 .29 .33 .81 1.12 1.15 1.3 1.35 1.77
 0
0 914 933 938 780 727 621 618 649 769 773 783 764 0
$
 X23$  FFAR (MK40) CX VS MACH NUMBER
1 0 9 1
  .001 .087 .213 .315 .818 1.168 1.416 1.535 1.681
 0
 1.15 .21 .177 .167 .527 2.864 2.301 2.03 1.805
 $
X9$ UNITY TABLE
  1 0 2 1   0 999   0   1 1
    $
 X9$ DUMMY TABLE
1 0 2 1   0 999   0   0 0
 $
 X23$ FFAR (MK40) CN VS MACH NO.
   1 0 9 1
  .001 .087 .213 .315 .818 1.168 1.416 1.535 1.681
   0
 .402 .371 .372 .373 .423 .488 .357 .336 .313
 $
X23$ FFAR (MK40) CN-Q VS MACH NO.
  1 0 9 1
 .001 .087 .213 .315 .818 1.168 1.416 1.535 1.681
  0
 3.04 2.735 2.762 2.796 3.358 2.859 1.365 1.303 1.254
 $
 X23$  FFAR (MK40) CM VS MACH NO.
 1 0 9 1
 .001 .087 .213 .315 .818 1.168 1.416 1.535 1.681
 0
2.131 1.837 1.859 1.889 2.572 3.241 1.914 1.722 1.613
  $
 X23$  FFAR (MK40) CMQ VS MACH NO.
 1 0 9 1
 .001 .087 .213 .315 .818 1.168 1.416 1.535 1.681
```

```
0
 16.79 14.18 14.6 14.87 10.01 10.95 8.38 8.02 7.999
 $
  X23$ FFAR (MK40) CM-ALPHA VS MACH NO.
1 0 9 1
 .001 .087 .213 .315 .818 1.168 1.416 1.535 1.681
  0
 1.103 .9553 .9643 .9776 1.317 1.623 .9391
 .8399 .7812
$
 X23$ FFAR (MK40) CN-ALPHA VS MACH NO.
  1 0 9 1
   .001 .087 .213 .315 .818 1.168 1.416 1.535 1.681
  0
  .2077 .1919 .1922 .1928 .2156 .2449 .1772
  .1663 .1537
    $
X9$  FFAR (MK40) CG COASTING
 1 0 2 1
 1.77 80
 0
1.334 1.334
   $
 X9$  FFAR (MK40) IXX COASTING
 1 0 2 1
 1.77 80
0
 .3429 .3429
 $
 X9$  FFAR (MK40) IYY COASTING
 1 0 2 1
 1.77 80
0
40.6 40.6
 $
X9$  FFAR (MK40) WEIGHT COASTING
  1 0 2 1
 1.77 80
0
5.2 5.2
 $
X9$  FFAR (MK40) THRUST COASTING
 1 0 2 1
 1.77 80
0
0 0
  $
 X31$ FFAR (MK40) CX COASTING
```

```
1 0 13 1
.002 .149 .218 .469 .591 .69 .774 .851 .926
1.045 1.305 1.654 1.681
0
1.031 .207 .191 .164 .175 .21 .332 .652 .977
3.728 2.638 1.84 1.805
$
X31$  FFAR (MK40) CN COASTING
1 0 13 1
.002 .149 .218 .469 .591 .69 .774 .851 .926
1.045 1.305 1.654 1.681
0
.387 .371 .371 .377 .327 .414 .423 .434
.446 .499 .46 .318 .313
$
X31$  FFAR (MK40) CNQ COASTING
1 0 13 1
.002 .149 .218 .469 .591 .69 .774 .851 .926
1.045 1.305 1.654 1.681
0
3.297 3.117 3.125 3.199 2.619 3.613 3.708
3.67 3.55 3.539 1.702 1.277 1.254
$
X31$  FFAR (MK40) CM COASTING
1 0 13 1
.002 .149 .218 .469 .591 .69 .774 .851 .926
1.045 1.305 1.654 1.681
0
2.498 2.319 2.323 2.375 1.811 2.793 2.889
3.016 3.16 3.635 3.29 1.662 1.613
$
X31$  FFAR (MK40) CMQ COASTING
1 0 13 1
.002 .149 .218 .469 .591 .69 .774 .851 .926
1.045 1.305 1.654 1.681
0
20.118 18.479 18.74 19.23 13.8 13.57 12.51 12.07
12.29 12.46 12.13 8.14 7.9998
$
X31$  FFAR (MK40) CM-ALPHA COASTING
1 0 13 1
.002 .149 .218 .469 .591 .69 .774 .851 .926
1.045 1.305 1.654 1.681
0
1.295 1.203 1.203 1.223 .9393 1.444 1.493 1.553
1.62 1.846 1.633 .8061 .7812
$
X31$  FFAR (MK40) CN-ALPHA COASTING
```

```
1 0 13 1
 .002 .149 .218 .469 .591 .69 .774 .851 .926
 1.045 1.305 1.654 1.681
 0
.2001 .1918 .1919 .1941 .169 .2139 .2183 .2221 .2274
 .2529 .2295 .1561 .1537
 $
X1 0 0 0$
 FFAR MK40 MOTOR 6-D SARA LOUISE KRALEWSKI
TIME(SEC)  ALT(ft)
 X 0 95 28 0 0 0 31$
6001 20.42      PAYLOAD AND VEHICLE WEIGHT
43 0.0001       MAX TRUNCATION ERROR ALLOWED
50 1            OBLATE ROTATING EARTH
 51 0           NO WINDS
52 1            '62 STD ATMOSPHERE
 53 .001953125  INITIAL DELTA TIME(SEC)
55 1            THRUST ON
56 0            RUNGE-KUTTA INTEGRATION
57 1            VARIABLE DELTA T
59 3            BINARY TAPE OUTPUT
60 1            INPUT BODY RATES
 175 3600       ROLL RATE(DEG/SEC)
176 2.0         PITCH RATE(DEG/SEC)
 177 0.0        YAW RATE(DEG/SEC)
 61 9.765625E-4 MINIMUM DELTA T
 62 1.0         MAXIMUM DELTA T
64 2            POSITION INPUT OPTION 2
100 0.          CURRENT TIME
 101 0          INITIAL TIME
107 65.129      LATITUDE
106 -147.49     LONGITUDE
108 647.0       ALTITUDE
65 4            VELOCITY INPUT OPTION 4
120 1.          VELOCITY
121 82          VELOCITY VECTOR ELEVATION
122 0.          VELOCITY VECTOR AZIMUTH
66 2            BODY ORIENTATION INPUT OPTION 2
 138 0.0        BANK ANGLE
139 82          BODY ELEVATION
140 0.          BODY AZIMUTH
 67 400000      HEIGHT OF SENSIBLE ATMOSPHERE
68 2            NONLINEAR AERODYNAMICS
70 0            DO NOT USE THIS OPTION
 73 10          TAKE 10 STEPS BEFORE DOUBLING DELTA T
156 .04125      REFERENCE AREA
157 .2292       REF DIAMETER
173 -147.49     REFERENCE LONGITUDE
```

```
174 65.129    REFERENCE LATITUDE
600 1         STOP WHEN
601 100       CURRENT TIME
602 1.77      EQUALS 1 SEC
650 0         PRINT WHEN
651 100       CURRENT TIME CHANGES BY
652 0.1       A SECOND
656 0         WRITE THE OUTPUT TAPE WHEN
657 100       CURRENT TIME CHANGES BY
658 0.1       A TENTH    OF A SECOND
701 6         PRINT ON FILE 6
702 3         NUMBER OF INDICES TO PRINT
703  100  704  108
815 2         FREQUENCY ANALYSIS OPTION ON
817 0.15915494  CONVERT RAD/SEC TO CPS IN FREQUENCY ROUTINE
900 0.0       CONSTANT=ZERO
901 1.0       CONSTANT=UNITY
902 -1.0      MULTIPLIER
903 -0.08333333  CONSTANT(FT/IN)
904 0.0       FIN CANT (RAD)
905 0.0       X WIND
906 0.0       Y WIND
907 0.0       YCG
908 0.        ZCG
909 9.2       PAYLOAD WEIGHT
911 1.0       APACHE THRUST MULTIPLIER
1000 0.       THRUST MISALIGNMENT
1001 90.0     THRUST MISALIGNMENT IN BODY PITCH PLANE
1022 .27083   NOZZLE EXIT AREA
1064 1        THRUST AND WEIGHT RATE OPTION 1
1074 1        WEIGHT OPTION 1
1084 0        ATTITUDE CONTROL OPTION 0
1144 0.0      START TIME FOR BODY MOMENT CALCULATIONS
1145 999      STOP TIME FOR BODY MOMENT CALCULATIONS
1164 1        ONE ROCKET
1208 -4.11    THRUST APPLICATION POINT
1209 0.       Y THRUST OFFSET
1210 0.       Z THRUST OFFSET
1238 77       USE TABLES 77-79 FOR CG POSITIONS
1271 0        COORDINATE OPTION
5000 4        SCALE 4 VARIABLES
5001 175      ROLL RATE IN DEG/SEC
5101 2.7777778E-3 TO ROLL RATE IN CPS
5002 531      PDOT IN DEG/SEC2
5102 2.7777778E-3 TO PDOT IN CYCLES/SEC2
5003 108      ALTITUDE IN FEET
5103 3.048E-4   TO ALTITUDE IN KILOMETERS
5004 578      RANGE IN FEET
```

```
  5104 1.645788E-4  TO RANGE IN NAUTICAL MILES
 5410 1        JET DAMPING ON
 5411 0        NO EXTERNAL FORCES
5412 0         NO EXTERNAL MOMENTS
 5329 0.       TAIL MISALIGNMENT (RAD)
 5498 0        LABELS AT BEGINNING OF PHASE ONLY
 5500 3        NUMBER OF INDICES TO WRITE ON TAPE
 5501  100 5502  108
 $
 1  9  7 108   0   0  335  0  905  0  0  0  0 $ WIND X
2  9  7 108   0   0  336  0  906  0  0  0  0 $ WIND Y
 3  9  7 108   0   0  337  0  900 -1  0  0  0 $ WIND Z = 0.
4  9  7 108   0   0  338  0  901 -1  0  0  0 $ PRESSURE RATIO
5  9  7 108   0   0  339  0  901 -1  0  0  0 $ DENSITY RATIO
6  9  7 108   0   0  340  0  901 -1  0  0  0 $ SOUND SPEED RATIO
 7  9  7 108   0   0  341  0  901 -1  0  0  0 $ VISCOSITY RATIO
16  9  6 401   0   0  417  0  902  0  0  0  0 $ CD THRUSTING
23  9  9 401   0   0  424  0  901  0  0  0  0 $ CN
 24  9 10 401   0   0  425  0  901  0  0  0  0 $ CNQ
25  9 13 401   0   0  426  0  901  0  0  0  0 $ CN ALPHA
 26  9  7 401   0   0  427  0  900 -1  0  0  0 $ CNP ALPHA = 0
 27  9  7 401   0   0  483  0  904  0  0  0  0 $ CL DELTA
28  9  7 401   0   0  484  0  901  0  0  0  0 $ CLP
 31  9 11 401   0   0  487  0  902  0  0  0  0 $ CM
 32  9 12 401   0   0  488  0  902  0  0  0  0 $ CMQ
37  9 14 401   0   0  493  0  902  0  0  0  0 $ CM ALPHA
41  9  5 100   0   0 1042  0  911  0  0  0  0 $ THRUST
61  9  4 100   0   0 1054  0  901  0  0  0  0 $ WEIGHT
 71  9  2 100   0   0  161  0  901  0  0  0  0 $ IXX
 72  9  7 100   0   0  162  0  900  0  0  0  0 $ IXY = 0.
73  9  7 100   0   0  163  0  900  0  0  0  0 $ IXZ = 0.
74  9  3 100   0   0  165  0  901  0  0  0  0 $ IYY
 75  9  7 100   0   0  166  0  900  0  0  0  0 $ IYZ = 0.
  76  9  3 100   0   0  169  0  901  0  0  0  0 $ IZZ
77  9  1 100   0   0 1205  0  901  0  0  0  0 $ XCG
78  9  8 100   0   0 1206  0  907 -1  0  0  0 $ YCG
79  9  8 100   0   0 1207  0  908 -1  0  0  0 $ ZCG
 X 1 1 0 0 $
  COAST TO APOGEE
 X0 8 0 0 0 0 34 $
6001 14.4
55 0
601 121
602 0.
53 1
650 0
 651 100
 652 .1
```

```
$
 X1 1 0 0 $
COAST TO IMPACT
 X0 7 0 0 0 0 34 $
601 108 602 0.
 650 0
651 100
 652 .1
601 100 602 1220
$
FFAR MK40 MOTOR 6-D SARA LOUISE KRALEWSKI
NORMAL MODE
OUTPUT FILE  6 INDICES
PHASE   1

100.TIME(SEC)    108.ALT(ft)         0.

0.0000000D+00    6.4700000D+02    0.0000000D+00
1.0058594D-01    6.4951088D+02    0.0000000D+00
2.0117188D-01    6.6063324D+02    0.0000000D+00
3.0175781D-01    6.7942834D+02    0.0000000D+00
4.0234375D-01    7.0483035D+02    0.0000000D+00
5.0292969D-01    7.3680552D+02    0.0000000D+00
6.0351563D-01    7.7550825D+02    0.0000000D+00
7.0507813D-01    8.2157010D+02    0.0000000D+00
8.0566406D-01    8.7426021D+02    0.0000000D+00
9.0625000D-01    9.3418883D+02    0.0000000D+00
1.0068359D+00    1.0017875D+03    0.0000000D+00
1.1074219D+00    1.0775770D+03    0.0000000D+00
1.2080078D+00    1.1620628D+03    0.0000000D+00
1.3085938D+00    1.2554660D+03    0.0000000D+00
1.4091797D+00    1.3575580D+03    0.0000000D+00
1.5097656D+00    1.4667045D+03    0.0000000D+00
1.6103516D+00    1.5804668D+03    0.0000000D+00
1.7109375D+00    1.6964469D+03    0.0000000D+00
1.7700000D+00    1.7646538D+03    0.0000000D+00

EXECUTION TIME OF LAST PHASE =      1.15 MINUTES
 TOTAL EXECUTION TIME OF THIS SG-GEM RUN =      1.15 MINUTES1

COAST TO APOGEE
 NORMAL MODE
OUTPUT FILE  6 INDICES
PHASE   2

   100.TIME(SEC)    108.ALT(ft)         0.

1.7700000D+00    1.7646538D+03    0.0000000D+00
```

1.8950000D+00	1.9068272D+03	0.0000000D+00
2.0200000D+00	2.0456207D+03	0.0000000D+00
2.1450000D+00	2.1813939D+03	0.0000000D+00
2.2700000D+00	2.3144476D+03	0.0000000D+00
2.3950000D+00	2.4450366D+03	0.0000000D+00
2.5200000D+00	2.5733787D+03	0.0000000D+00
2.6450000D+00	2.6996618D+03	0.0000000D+00
2.7700000D+00	2.8240493D+03	0.0000000D+00
2.8950000D+00	2.9466842D+03	0.0000000D+00
3.0200000D+00	3.0676927D+03	0.0000000D+00
3.2700000D+00	3.3052651D+03	0.0000000D+00
3.5200000D+00	3.5375248D+03	0.0000000D+00
3.7700000D+00	3.7650843D+03	0.0000000D+00
4.0200000D+00	3.9884459D+03	0.0000000D+00
4.2700000D+00	4.2079214D+03	0.0000000D+00
4.5200000D+00	4.4236340D+03	0.0000000D+00
4.7700000D+00	4.6356835D+03	0.0000000D+00
5.0200000D+00	4.8441634D+03	0.0000000D+001

COAST TO APOGEE

5.2700000D+00	5.0491610D+03	0.0000000D+00
5.5200000D+00	5.2507581D+03	0.0000000D+00
6.0200000D+00	5.6440530D+03	0.0000000D+00
6.5200000D+00	6.0246078D+03	0.0000000D+00
7.0200000D+00	6.3929178D+03	0.0000000D+00
7.5200000D+00	6.7494230D+03	0.0000000D+00
8.0200000D+00	7.0945156D+03	0.0000000D+00
8.5200000D+00	7.4285461D+03	0.0000000D+00
9.0200000D+00	7.7518286D+03	0.0000000D+00
9.5200000D+00	8.0646452D+03	0.0000000D+00
1.0020000D+01	8.3672495D+03	0.0000000D+00
1.0520000D+01	8.6598702D+03	0.0000000D+00
1.1520000D+01	9.2159656D+03	0.0000000D+00
1.2520000D+01	9.7343532D+03	0.0000000D+00
1.3520000D+01	1.0216194D+04	0.0000000D+00
1.4520000D+01	1.0662437D+04	0.0000000D+00
1.5520000D+01	1.1073854D+04	0.0000000D+00
1.6520000D+01	1.1451073D+04	0.0000000D+00
1.7520000D+01	1.1794599D+04	0.0000000D+001

COAST TO APOGEE

1.8520000D+01	1.2104825D+04	0.0000000D+00
1.9520000D+01	1.2381992D+04	0.0000000D+00
2.0520000D+01	1.2626270D+04	0.0000000D+00
2.1520000D+01	1.2837806D+04	0.0000000D+00
2.2520000D+01	1.3016731D+04	0.0000000D+00

2.3520000D+01	1.3163150D+04	0.0000000D+00
2.4520000D+01	1.3277153D+04	0.0000000D+00
2.5520000D+01	1.3358818D+04	0.0000000D+00
2.6520000D+01	1.3408206D+04	0.0000000D+00
2.7520000D+01	1.3425367D+04	0.0000000D+00
2.7552948D+01	1.3425384D+04	0.0000000D+00

EXECUTION TIME OF LAST PHASE = 0.02 MINUTES
TOTAL EXECUTION TIME OF THIS SG-GEM RUN = 1.18 MINUTES1

COAST TO IMPACT
NORMAL MODE
OUTPUT FILE 6 INDICES
PHASE 3

100.TIME(SEC)	108.ALT(ft)	0
2.7552948D+01	1.3425384D+04	0.0000000D+00
2.8552948D+01	1.3409298D+04	0.0000000D+00
2.9552948D+01	1.3361066D+04	0.0000000D+00
3.0552948D+01	1.3280738D+04	0.0000000D+00
3.1552948D+01	1.3168371D+04	0.0000000D+00
3.2552948D+01	1.3024042D+04	0.0000000D+00
3.3552948D+01	1.2847837D+04	0.0000000D+00
3.4552948D+01	1.2639856D+04	0.0000000D+00
3.5552948D+01	1.2400222D+04	0.0000000D+00
3.6552948D+01	1.2129071D+04	0.0000000D+00
3.7552948D+01	1.1826562D+04	0.0000000D+00
3.8552948D+01	1.1492886D+04	0.0000000D+00
3.9552948D+01	1.1128364D+04	0.0000000D+00
4.0552948D+01	1.0733413D+04	0.0000000D+00
4.1552948D+01	1.0308529D+04	0.0000000D+00
4.2552948D+01	9.8542893D+03	0.0000000D+00
4.3552948D+01	9.3713583D+03	0.0000000D+00
4.4552948D+01	8.8604887D+03	0.0000000D+00
4.5552948D+01	8.3225225D+03	0.0000000D+001

COAST TO IMPACT

4.6552948D+01	7.7583902D+03	0.0000000D+00
4.7552948D+01	7.1691079D+03	0.0000000D+00
4.8552948D+01	6.5557729D+03	0.0000000D+00
4.9552948D+01	5.9195569D+03	0.0000000D+00
5.0552948D+01	5.2616981D+03	0.0000000D+00
5.1552948D+01	4.5834915D+03	0.0000000D+00
5.2552948D+01	3.8862774D+03	0.0000000D+00
5.3552948D+01	3.1714296D+03	0.0000000D+00
5.4552948D+01	2.4403425D+03	0.0000000D+00

5.5552948D+01	1.6944177D+03	0.0000000D+00
5.6552948D+01	9.3505163D+02	0.0000000D+00
5.7552948D+01	1.6362254D+02	0.0000000D+00
5.8552948D+01	-6.1852094D+02	0.0000000D+00
5.9552948D+01	-1.4100705D+03	0.0000000D+00
6.0552948D+01	-2.2097671D+03	0.0000000D+00
6.1552948D+01	-3.0164092D+03	0.0000000D+00
6.2552948D+01	-3.8288585D+03	0.0000000D+00
6.3552948D+01	-4.6460449D+03	0.0000000D+00
6.4552948D+01	-5.4669693D+03	0.0000000D+001

COAST TO IMPACT

6.5552948D+01	-6.2907059D+03	0.0000000D+00
6.6552948D+01	-7.1164019D+03	0.0000000D+00
6.7552948D+01	-7.9432772D+03	0.0000000D+00
6.8552948D+01	-8.7706230D+03	0.0000000D+00
6.9552948D+01	-9.5977988D+03	0.0000000D+00
7.0552948D+01	-1.0424230D+04	0.0000000D+00
7.1552948D+01	-1.1249403D+04	0.0000000D+00
7.2552948D+01	-1.2072863D+04	0.0000000D+00
7.3552948D+01	-1.2894211D+04	0.0000000D+00
7.4552948D+01	-1.3713095D+04	0.0000000D+00
7.5552948D+01	-1.4529212D+04	0.0000000D+00

RUN TERMINATED BECAUSE ALTITUDE IS NEGATIVE
RUN TERMINATED BECAUSE ALTITUDE IS NEGATIVE
7.6552948D+01 -1.5342299D+04 0.0000000D+00
EXECUTION TIME OF LAST PHASE = 0.02 MINUTES

TOTAL EXECUTION TIME OF THIS SG-GEM RUN = 1.20 MINUTES

APPENDIX H: Aerodynamic Coefficient

H.1 Aerodynamic Coefficient Summary Spreadsheet

DATCOM:
Alpha = 2 deg Beta = 8 deg

TIME (sec)	(Rogers) Mach No.	(Rogers) Altitude 82 deg Launch Ele. (feet ASL)	(C.G. spread sheet) XCG (center of gravity) (inches from TNT)	(DATCOM) Cd (drag coeff)	(DATCOM) Ca (axial coeff)
0.00	0.001	647.00	19.6890	1.1630	1.1500
0.10	0.087	650.00	19.5670	0.2230	0.2100
0.20	0.213	665.00	19.4380	0.1890	0.1770
0.30	0.315	692.00	19.3025	0.1800	0.1670
0.80	0.818	975.00	18.4725	0.5410	0.5270
1.10	1.168	1275.00	17.8380	2.8790	2.8640
1.30	1.416	1535.00	17.3800	2.3120	2.3010
1.40	1.535	1684.00	17.1240	2.0400	2.0300
1.70	**1.681**	**2178.00**	**16.0935**	**1.8150**	**1.8050**
1.80	1.654	2345.00	16.0060	1.8500	1.8400
2.80	1.305	3815.00	16.0060	2.6530	2.6380
4.10	1.045	5316.00	16.0060	3.7430	3.7280
5.50	0.926	6665.00	16.0060	0.9920	0.9770
7.00	0.851	7969.00	16.0060	0.6700	0.6520
8.70	0.774	9324.00	16.0060	0.3460	0.3320
10.70	0.690	10729.00	16.0060	0.2250	0.2100
13.20	0.591	12273.00	16.0060	0.1860	0.1750
16.50	0.469	13947.00	16.0060	0.1770	0.1640
23.80	0.218	16316.00	16.0060	0.2040	0.1910
25.90	0.149	16679.00	16.0060	0.2200	0.2070
30.40	0.002	16999.00	16.0060	1.0440	1.0310

(DATCOM)	(Calculate)	(DATCOM)	(DATCOM) reference diameter (ft) 0.229166667	(Calculate)
Cna (slope of normal force) (1/deg)	**Cna** (slope of normal force) (1/rad)	**Cn** (normal force coeff)	**XCP** (static margin) (x-CP)/d	**CP** (center of pressure) (inches)
0.2077	11.9003	0.4020	-5.3010	34.2668
0.1919	10.9951	0.3710	-4.9550	33.1933
0.1922	11.0122	0.3720	-5.0030	33.1963
0.1928	11.0466	0.3730	-5.0610	33.2203
0.2156	12.3530	0.4230	-6.0820	35.1980
0.2449	14.0317	0.4880	-6.6470	36.1173
0.1772	10.1528	0.3570	-5.3660	32.1365
0.1663	9.5283	0.3360	-5.1210	31.2068
0.1537	8.8064	**0.3130**	**-5.1500**	**30.2560**
0.1561	8.9439	0.3180	-5.2280	30.3830
0.2295	13.1494	0.4600	-7.1570	35.6878
0.2529	14.4901	0.4990	-7.2900	36.0535
0.2274	13.0291	0.4460	-7.0920	35.5090
0.2221	12.7254	0.4340	-6.9550	35.1323
0.2183	12.5077	0.4230	-6.8360	34.8050
0.2139	12.2556	0.4140	-6.7450	34.5548
0.1690	9.6830	0.3270	-5.5400	31.2410
0.1941	11.1211	0.3770	-6.3050	33.3448
0.1919	10.9951	0.3710	-6.2570	33.2128
0.1918	10.9893	0.3710	-6.2520	33.1990
0.2001	11.4649	0.3870	-6.4580	33.7655

(Calculate) CP (center of pressure) (feet)	(Calculate) Cmq (pitch damping moment) (1/deg)	(DATCOM) Cmq + Cmad (1/deg) (pitch moment coeff due to pitch rate) (pitch moment coeff due to rate cng of alpha)
2.8556	-11.6730	-16.7970
2.7661	-9.4231	-14.1820
2.7664	-9.6215	-14.6105
2.7684	-9.8767	-14.8753
2.9332	-15.9504	-10.0131
3.0098	-21.6406	-10.9518
2.6780	-10.2046	-8.3829
2.6006	-8.7223	-8.0237
2.5213	**-8.1530**	**-7.9998**
2.5319	-8.5330	-8.1415
2.9740	-23.5112	-12.1365
3.0045	-26.8803	-12.4602
2.9591	-22.8748	-12.2914
2.9277	-21.4869	-12.0780
2.9004	-20.4027	-12.5146
2.8796	-19.4628	-13.5670
2.6034	-10.3738	-13.8266
2.7787	-15.4321	-19.2366
2.7677	-15.0258	-18.7430
2.7666	-14.9940	-18.4790
2.8138	-16.6906	-20.1180

(DATCOM) **Cnad** normal force coeff due to rate change of alpha (1/deg)	(DATCOM) **Cnq** (normal force coeff due to pitch) (1/deg)
1.4640	3.0400
1.4450	2.7350
1.4480	2.7620
1.4500	2.7960
1.3100	3.3580
1.4790	2.8590
1.2040	1.3650
1.2020	1.3030
1.1750	**1.2540**
1.1860	1.2770
1.2170	1.7020
1.5640	3.5390
1.3700	3.5500
1.3660	3.6700
1.4080	3.7080
1.4330	3.6130
1.4010	2.6190
1.4430	3.1990
1.4430	3.1250
1.4440	3.1170
1.4550	3.2970

(DATCOM) Cm (pitching moment coeff)	(DATCOM) Cma (pitching moment coeff deriv w/ alpha) (1/deg)	(DATCOM) Cl (Cll) (Aero moment in X dir) (rolling moment coeff)
-2.1310	-1.1030	-0.0010
-1.8370	-0.9553	-0.0040
-1.8590	-0.9643	-0.0050
-1.8890	-0.9776	-0.0060
-2.5720	-1.3170	-0.0100
3.2410	-1.6230	-0.0120
-1.9140	-0.9391	-0.0070
-1.7220	-0.8399	-0.0050
-1.6130	**-0.7812**	**-0.0040**
-1.6620	-0.8061	-0.0040
-3.2900	-1.6330	-0.0110
-3.6350	-1.8460	-0.0130
-3.1600	-1.6200	-0.0120
-3.0160	-1.5530	0.0120
-2.8890	-1.4930	-0.0100
-2.7930	-1.4440	-0.0090
-1.8110	-0.9393	-0.0050
-2.3750	-1.2230	-0.0070
-2.3230	-1.2030	-0.0050
-2.3190	-1.2030	-0.0050
-2.4980	-1.2950	-0.0040

(Calculate) Wn (natural pitching frequency) (deg/sec)	Wn (natural pitching frequency) (cps)	(Calculate) P (spin rate) (cycles/sec)	(Calculate) P (spin rate) (deg/sec)	(Rogers) Velocity (ft/sec)
0.00	0.0000	0.000	0.000	1
0.22	0.0006	0.937	337.464	87
0.53	0.0015	2.311	831.888	213
0.79	0.0022	3.423	1232.136	315
2.42	0.0067	8.905	3205.908	818
3.87	0.0108	12.720	4579.308	1168
3.59	0.0100	15.424	5552.460	1416
3.69	0.0103	16.721	6019.416	1535
3.92	0.0109	18.400	6624.000	1681
3.93	0.0109	18.500	6660.000	1654
4.41	0.0123	12.000	4320.000	1305
3.76	0.0104	11.000	3960.000	1045
3.12	0.0087	8.500	3060.000	926
2.81	0.0078	7.400	2664.000	851
2.50	0.0070	7.100	2556.000	774
2.19	0.0061	6.000	2160.000	690
1.52	0.0042	4.500	1620.000	591
1.37	0.0038	3.500	1260.000	469
0.63	0.0018	1.500	540.000	218
0.43	0.0012	0.937	337.464	149
0.00	0.0000	0.000	0.000	0

(Calculate) IYY (lb ft^2)	(Calculate) Damping Ratio	(Calculate) Cmq + Cmad (1/rad) (pitch moment coeff due to pitch rate) (pitch moment coeff due to rate cng of alpha)	(Calculate) Cma (pitching moment coeff deriv w/ alpha) (1/rad)
44.27	0.02	-962.885	-63.229
44.26	1.60	-812.981	-54.762
43.89	4.03	-837.545	-55.278
43.71	6.05	852.724	-56.041
42.66	9.22	-573.999	-75.497
42.01	13.07	-627.810	-93.038
41.62	16.01	-480.550	-53.834
41.3	17.64	-459.956	-48.147
40.8	20.09	-458.587	-44.782
40.61	19.85	-466.710	-46.210
40.61	16.40	-695.723	-93.611
40.61	12.68	-714.279	-105.822
40.61	11.84	-704.603	-92.866
40.61	10.92	-692.369	-89.025
40.61	10.49	-717.397	-85.586
40.61	10.31	-777.726	-82.777
40.61	11.16	-792.608	-53.845
40.61	10.80	-1102.735	-70.108
40.61	4.93	-1074.439	-68.962
40.61	3.32	-1059.306	-68.962
40.61	0.00	-1153.261	-74.236

(Calculate)

Angle due to spin rate (rad)	Angle due to spin rate (deg)
0.0000	0.000
0.0076	0.433
0.0076	0.436
0.0076	0.437
0.0076	0.437
0.0076	0.438
0.0076	0.438
0.0076	0.438
0.0077	0.440
0.0078	0.449
0.0064	0.369
0.0074	0.423
0.0064	0.369
0.0061	0.349
0.0064	0.369
0.0061	0.349
0.0053	0.306
0.0052	0.300
0.0048	0.276
0.0044	0.253
0.0000	0.000

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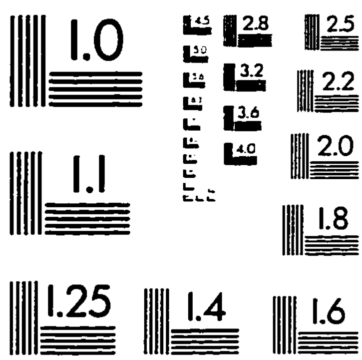
IMAGE EVALUATION TEST TARGET (QA-3)



150mm

6"

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